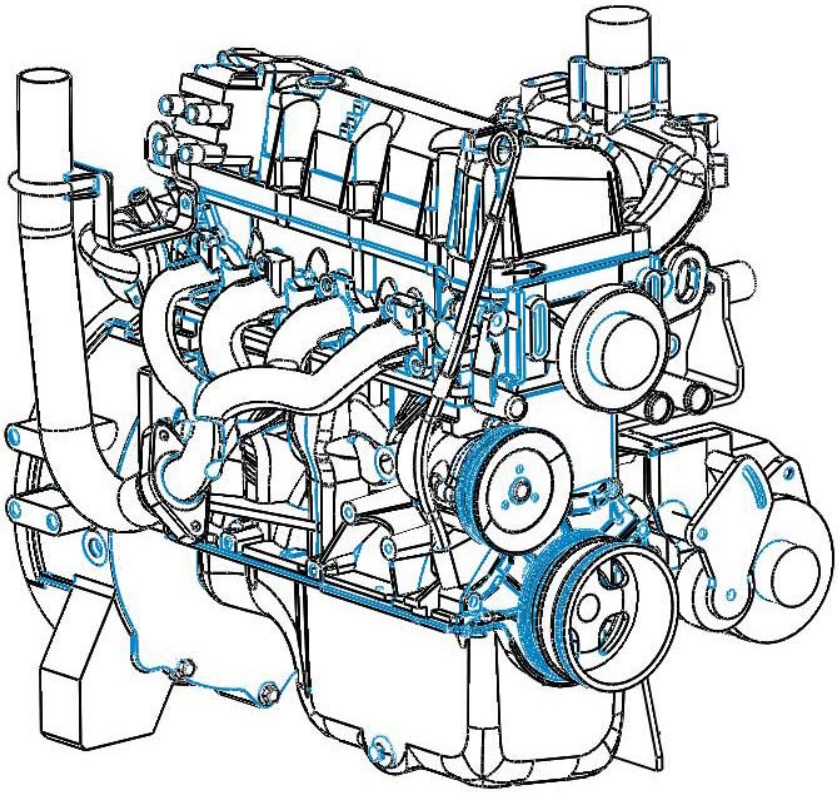
ENGINE DISTRIBUTORS INC.

TSG-416
1.6 LITER

INDUSTRIAL ENGINE SERVICE MANUAL



Powertrain Assemblies
& Components Provided
By Ford Component Sales

Ford Power Products

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Revision 0
December 2012

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Section Index

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Section 01 **GENERAL INFO**

Section 02 **ENGINE**

Section 03 **IGNITION**

Section 04 **FUEL**

Section 05 **COOLING**

Section 06 **CHARGING**

Section 07 **STARTER**

Section 08 **ENG. CONTROLS**

Section 09 **METRICS**

Section 10 **DISTRIBUTORS**

HEALTH & SAFETY

WARNING: THE FOLLOWING HEALTH AND SAFETY RECOMMENDATIONS SHOULD BE CAREFULLY OBSERVED

WARNING: CARRYING OUT CERTAIN OPERATIONS AND HANDLING SOME SUBSTANCES CAN BE DANGEROUS OR HARMFUL TO THE OPERATOR IF THE CORRECT SAFETY PRECAUTIONS ARE NOT OBSERVED. SUCH PRECAUTIONS ARE RECOMMENDED AT THE APPROPRIATE POINTS IN THIS BOOK. WARNING: WHILE IT IS IMPORTANT THAT THESE RECOMMENDED SAFETY PRECAUTIONS ARE OBSERVED, CARE NEAR MACHINERY IS ALWAYS NECESSARY, AND NO LIST CAN BE EXHAUSTIVE. ALWAYS BE CAUTIOUS TO AVIOD POTENTIAL SAFETY RISKS.

The following recommendations are for general guidance:

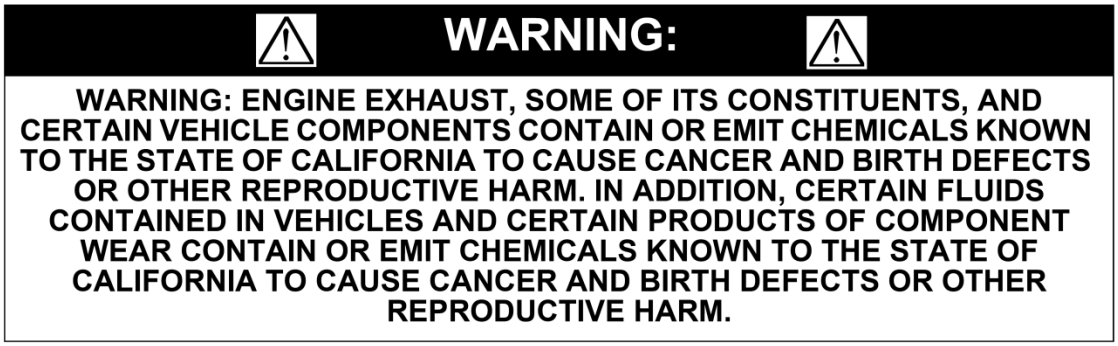
1. Always wear correctly fitting protective clothing which should be laundered regularly. Loose or baggy clothing can be extremely dangerous when working on running engines or machinery. Clothing which becomes impregnated with oil or other substances can constitute a health hazard due to prolonged contact with the skin even through underclothing.

2. So far as practicable, work on or close to engines or machinery only when they are stopped. If this is not practicable, remember to keep tools, test equipment and all parts of the body well away from the moving parts of the engine or equipment—fans, drive belts and pulleys are particularly dangerous. The electric cooling fan used on some installations is actuated automatically when the coolant reaches a specified temperature. For this reason, care should be taken to ensure that the ignition/isolating switch is OFF when working in the vicinity of the fan as an increase in coolant temperature may cause the fan suddenly to operate.

3. Avoid contact with exhaust pipes, exhaust manifolds and silencers when an engine is, or has recently been running; these can be very hot and can cause severe burns.

4. Many liquids used in engines or vehicles are harmful if taken internally or splashed into the eyes. In the event of accidentally swallowing gasoline (petrol), oil, diesel fuel, antifreeze, battery acid etc, do NOT encourage vomiting and OBTAIN QUALIFIED MEDICAL ASSISTANCE IMMEDIATELY.

Wear protective goggles when handling liquids which are harmful to the eyes; these include ammonia and battery acid. If any of these substances are splashed in the eyes, wash out thoroughly with clean water and OBTAIN QUALIFIED MEDICAL ASSISTANCE IMMEDIATELY.



IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all industrial engines as well as the personal safety of the individual doing the work. This Service Manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

TSG-416 GENERAL INFORMATION

INDEX

Subject

General Information **Page**

Introduction..... 01 – 3
Safety Notice..... 01 – 3
Notes, Cautions, and Warnings..... 01 – 3
Battery Handling and Charging..... 01 – 4
Forward..... 01 – 5
Engine Identification..... 01 – 5
Parts and Service..... 01 – 5
Description and Operation..... 01 – 5

Diagnosis and Testing

Special Tools..... 01 – 6
Inspection and Verification..... 01 – 7
Symptom Chart..... 01 – 7
PCV System Malfunction..... 01 – 10
Engine Oil Leaks..... 01 – 10
Compression Tests..... 01 – 12
Cylinder Leakage Detection..... 01 – 13
Intake Manifold Vacuum Test..... 01 – 13
Excessive Engine Oil Consumption..... 01 – 15
Oil Pressure Test..... 01 – 16
Valve Train Analysis – Static..... 01 – 17
Valve Train Analysis – Dynamic..... 01 – 17
Camshaft Love Lift..... 01 – 18
Hydraulic Valve Lash Adjuster..... 01 – 19

General Service Procedures

Camshaft Journal Diameter..... 01 – 20
Camshaft Journal Clearance..... 01 – 20
Camshaft Lobe Surface..... 01 – 20
Camshaft Lobe Lift..... 01 – 21
Camshaft Runout..... 01 – 21
Camshaft End Play..... 01 – 21
Crankshaft Main Bearing Journal Diameter..... 01 – 22
Crankshaft Main Bearing Journal Taper..... 01 – 22
Crankshaft Main Bearing Journal Clearance..... 01 – 23
Bearing Inspection..... 01 – 23
Crankshaft End Play..... 01 – 24
Crankshaft Runout..... 01 – 24
Cylinder Bore Taper..... 01 – 24
Cylinder Bore Out-of-Round..... 01 – 25
Piston Inspection..... 01 – 25
Piston Diameter..... 01 – 25
Piston to Cylinder Bore Clearance..... 01 – 25

INDEX (CONT.)

Subject	Page
General Service Procedures	
Piston Selection	01 – 26
Piston Ring End Gap	01 – 26
Piston Ring-to-Groove Clearance	01 – 27
Crankshaft Connecting Rod Journal Diameter	01 – 27
Crankshaft Connection Rod Journal Taper	01 – 27
Connecting Rod Cleaning	01 – 27
Connecting Rod Larger End Bore	01 – 28
Piston Pin Diameter	01 – 28
Connecting Rod Bushing Diameter	01 – 28
Connecting Rod Bend	01 – 28
Connecting Rod Twist	01 – 28
Connecting Rod Piston Pin Side Clearance	01 – 29
Connecting Rod Journal Clearance	01 – 29
Bearing Inspection	01 – 30
Roller Follower Inspection	01 – 30
Hydraulic Lash Adjuster Inspection	01 – 30
Valve Stem Diameter	01 – 31
Valve Stem-to-Valve Guide Clearance	01 – 31
Valve Inspection	01 – 31
Valve Guide Inner Diameter	01 – 32
Valve Guide Reaming	01 – 32
Valve Spring Installed Length	01 – 32
Valve Spring Free Length	01 – 32
Valve Spring Out-of-Square	01 – 32
Valve Spring Compression Pressure	01 – 33
Valve and Seat Refacing Measurements	01 – 33
Valve Seat Width	01 – 33
Valve Seat Runout	01 – 33
Flywheel Inspection	01 – 34
Oil Pump Gear Radial Clearance	01 – 34
Oil Pump Rotor Inspection	01 – 34
Oil Pump Side Clearance	01 – 34
Cylinder Bore Honing	01 – 35
Cylinder Bore Cleaning	01 – 35
Cylinder Bore Core Plug Replacement	01 – 36
Cylinder Bore Repair – Cast Iron Porosity Defects	01 – 36
Cylinder Block – Distortion	01 – 36
Spark Plug Thread Repair	01 – 38
Exhaust Manifold Straightness	01 – 39
SPECIFICATIONS	**01 – 40**

GENERAL INFORMATION

Introduction

This section covers various engine tests, adjustments, service procedures and cleaning/inspection procedures. Engine assembly and service specifications appear at the end of the Section 02.

For engine disassembly, assembly, installation, adjustment procedures and specifications, refer to Section 02.

This engine incorporates a closed-type crankcase ventilation system.

To maintain the required performance level, the fuel system, ignition system and engine must be kept in good operating condition and meet recommended adjustment specifications.

Before replacing damaged or worn engine components such as the crankshaft, cylinder head, valve guide, valves, camshaft or cylinder block, make sure part(s) is not serviceable.

WARNING: TO AVOID THE POSSIBILITY OF PERSONAL INJURY OR DAMAGE, DO NOT OPERATE THE ENGINE UNTIL THE FAN BLADE HAS FIRST BEEN EXAMINED FOR POSSIBLE CRACKS OR SEPARATION.

CAUTION: Use of abrasive grinding discs to remove gasket material from the engine sealing surfaces during repair procedures can contribute to engine damage and wear. Airborne debris and abrasive grit from the grinding disc may enter the engine through exposed cavities causing premature wear and eventual engine damage.

Engine Distributors Inc. (EDI) does not recommend using abrasive grinding discs to remove engine gasket material. Use manual gasket scrapers for removing gasket material from the engine sealing surfaces. Take added care to prevent scratching or gouging aluminum sealing surfaces.

Safety Notice

There are numerous variations in procedures, techniques, tools and parts for servicing equipment, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from the instructions provided in this Manual must first establish that neither personal safety nor equipment integrity are compromised by the choice of methods, tools or parts.

Notes, Cautions, and Warnings

As you read through the procedures, you will come across NOTES, CAUTIONS, and WARNINGS. Each one is there for a specific purpose. NOTES gives you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the equipment. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on the equipment.

GENERAL WARNINGS:
TO HELP AVOID INJURY:

- **ALWAYS WEAR SAFETY GLASSES FOR EYE PROTECTION.**
- **USE SAFETY STANDS WHENEVER A PROCEDURE REQUIRES YOU TO BE UNDER THE EQUIPMENT.**
- **BE SURE THAT THE IGNITION SWITCH IS ALWAYS IN THE OFF POSITION, UNLESS OTHERWISE REQUIRED BY THE PROCEDURE.**
- **SET THE PARKING BRAKE (IF EQUIPPED) WHEN WORKING ON THE EQUIPMENT. IF YOU HAVE AN AUTOMATIC TRANSMISSION, SET IT IN PARK (ENGINE OFF) OR NEUTRAL (ENGINE ON) UNLESS INSTRUCTED OTHERWISE FOR A SPECIFIC OPERATION. PLACE WOOD BLOCKS (4"X 4" OR LARGER) TO THE FRONT AND REAR SURFACES OF THE TIRES TO PROVIDE FURTHER RESTRAINT FROM INADVERTENT EQUIPMENT MOVEMENT.**
- **OPERATE THE ENGINE ONLY IN A WELL VENTILATED AREA TO AVOID THE DANGER OF CARBON MONOXIDE.**
- **KEEP YOURSELF AND YOUR CLOTHING AWAY FROM MOVING PARTS WHEN THE ENGINE IS RUNNING, ESPECIALLY THE FAN BELTS.**
- **TO PREVENT SERIOUS BURNS, AVOID CONTACT WITH HOT METAL PARTS SUCH AS THE RADIATOR, EXHAUST MANIFOLD, TAIL PIPE, CATALYTIC CONVERTER AND MUFFLER.**
- **DO NOT SMOKE WHILE WORKING ON THE EQUIPMENT.**
- **ALWAYS REMOVE RINGS, WATCHES, LOOSE HANGING JEWELRY, AND LOOSE CLOTHING BEFORE BEGINNING TO WORK ON THE EQUIPMENT. TIE LONG HAIR SECURELY BEHIND THE HEAD.**
- **KEEP HANDS AND OTHER OBJECTS CLEAR OF THE RADIATOR FAN BLADES. ELECTRIC COOLING FANS CAN START TO OPERATE AT ANY TIME BY AN INCREASE IN UNDERHOOD TEMPERATURES, EVEN THOUGH THE IGNITION IS IN THE OFF POSITION. THEREFORE, CARE SHOULD BE TAKEN TO ENSURE THAT THE ELECTRIC COOLING FAN IS COMPLETELY DISCONNECTED WHEN WORKING UNDER THE HOOD.**

Battery Handling and Charging

The handling and correct use of lead acid batteries is not as hazardous provided that sensible precautions are observed and that operatives have been trained in their use and are adequately supervised.

It is important that all labeling on the battery is carefully read, understood and complied with. The format of the following symbols and labels is common to most brands of lead acid battery.

Typical Battery Labelling

	Explosive gases		Read relevant instructions
	Eye protection must be WORN.		Keep away from children
	No smoking or naked flames.	Pb	Do not dispose of as household waste.
	Corrosive acid	LEAD RETURN RECYCLE	Recycle (via recognized disposal system).
	Flush eyes immediately when contacted with acid		Electrical current may cause injury to personnel
	Caution/important notice.		

NOTE: Observe all manufacturers' instructions when using charging equipment.

CAUTION: Batteries should not be charged in the vehicle or equipment. May damage electrical components.

TSG-416 GENERAL INFORMATION

Forward

This book contains service information for the engine(s) listed on the title page.

The life of your engine unit and the delivery of the high performance built into it will depend on the care it receives throughout its life. It is the operator's responsibility to ensure that the engine is correctly operated. We consider it to be in your interests to enlist the aid of an authorized EDI Distributor, not only when repairs are required but also for regular maintenance. Distributors are listed at the back of this manual.

Engines manufactured by Ford Motor Company are available through EDI Distributors. When in need of parts or service, contact your local Authorized Distributor. In overseas territories, in the event of difficulties, communicate directly with the supervising EDI affiliated Company in your area whose address appears at the end of this book.

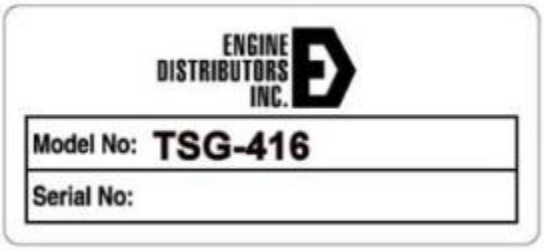
Where the terms "Right" or "Left" occur in this publication, they refer to the respective sides of the engine when viewed from the rear or flywheel end.

Pistons and valves are numbered from the front or timing cover end of the engine commencing at No. 1.

You may find that your engine assembly includes optional equipment not specifically covered in the following text. Nevertheless, the service procedures outlined in this book still apply to your engine.

Engine Identification

Because Ford Power Products markets such a wide range of industrial gasoline and diesel engines - manufactured both in the U.S. and overseas - it is important that you have as complete identification of the engine as possible in order to provide the correct replacement parts. Review the list in the back of this book, for an EDI distributor in your area. You can obtain a standard parts listing describing the parts. It remains a distributor function to identify the part number.



An identification Decal is affixed to the valve cover of the engine. The decal contains the engine serial number which identifies this unit from all others. Use all numbers when seeking information or ordering replacement parts for this engine.

Parts and Service

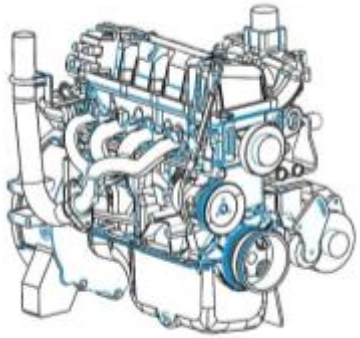
Replacement parts can be obtained through your local EDI Distributor listed in the back portion of this manual. They also may be found in the yellow pages under "Engines" or contact EDI directly at **1 800 220 2700**.

EDI Distributors are equipped to perform major and minor repairs. They are anxious to see that all of your maintenance and service needs are quickly and courteously completed.

Description and Operation

Section 01 of this manual covers general procedures and diagnosis of the engine system, including base engine repair procedures that would be common to most engines. Refer to Section 02 for more specific service information on the T**SG-416** engine.

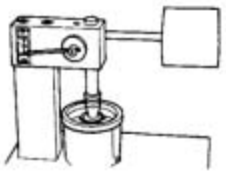
The T**SG-416** engine incorporates a closed positive crankcase ventilation system and an exhaust emission control system.



The engine's, fuel, ignition, emissions system and exhaust system all affect exhaust emission levels and must be maintained according to the maintenance schedule. Refer to the Maintenance and Operator's Handbook or contact your nearest EDI distributor listed in the back of this manual.

DIAGNOSIS AND TESTING

Special Tools

 FPP10023	Commercially Available Leakdown Tester	FPP10024	Compression Tester 014-00707 or Equivalent
FPP10025	Cup Shaped Adapter TOOL-6565-AB or Equivalent	FPP10026	Dial Indicator with Bracketry TOOL-4201-C or Equivalent
FPP10027	Engine Cylinder Leak Detection/Air Pressurization Kit 014-00705 or Equivalent	FPP10028	Engine Oil Pressure Gauge T73L-6600-A
FPP10029	12 Volt Master UV Diagnostic Inspection Kit 164-R0756 or Equivalent	FPP10030	Vacuum/Pressure Tester 164-R0253 or Equivalent

Special Service Tools called by the procedures can be obtained by calling:

1-800-ROTUNDA (1-800-768-8632)

Inspection and Verification

1. Verify the customer concern by operating the engine to duplicate the condition.

2. Visually inspect for obvious signs of mechanical and electrical damage:
   - Engine coolant leaks.
   - Engine oil leaks.
   - Fuel leaks.
   - Damaged or severely worn pads.
   - Loose mounting bolts, studs, and nuts.

3. If the inspection reveals obvious concerns that can be readily identified, repair as required.

4. If the concerns remain after the inspection, determine the symptoms and go to the symptom chart.

Symptom Chart

Condition	Possible Source	Action
Difficult Starting	Damaged starting system.	Refer to Section 07.
	Damaged charging system/battery.	Refer to Section 06.
	Burnt valve.	Replace valve.
	Worn piston.	Replace piston and pin.
	Worn piston rings or worn cylinder.	Repair or replace cylinder blocks.
	Damaged cylinder head gasket.	Replace cylinder head gasket.
	Damaged fuel system.	Refer to Section 04.
	Damaged ignition system.	Refer to Section 03.
	Spark plugs gapped incorrectly.	Check plug gap.
	Damaged hydraulic tappet or hydraulic lash adjuster.	Replace tappet or lash adjuster.
Poor Idling	Damaged hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster.
	Damaged hydraulic lash adjuster guide or hydraulic lash adjuster.	Replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Improper valve-to-valve seat contact.	Replace valve or valve seat.
	Damaged cylinder head gasket.	Replace cylinder head gasket.
	Malfunctioning or damaged fuel system.	Refer to Section 04 of this manual*.
	Malfunctioning or damaged ignition system.	Refer to Section 03 of this manual*.
	Spark plugs gapped incorrectly.	Check plug gap.
	Malfunctioning or damaged IAC motor or system.	Refer to Section 03 of this manual.
Abnormal combustion	Damaged hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster
	Damaged hydraulic lash adjuster guide or hydraulic lash adjuster.	Replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Burnt or sticking valve.	Repair or replace valve.
	Weak or broken valve spring	Replace valve spring
	Carbon accumulation in combustion chamber.	Eliminate carbon buildup.
	Malfunctioning or damaged fuel system	Refer to Section 04 of this manual*.
	Malfunctioning or damaged ignition system.	Refer to Section 03 of this manual*.

Condition	Possible Source	Action
Excessive Oil Consumption	Worn piston ring groove.	Replace piston and pin.
	Sticking piston rings.	Repair or replace piston rings.
	Worn piston or cylinders.	Repair or replace piston or cylinder blocks.
	Worn valve stem seal.	Replace valve stem seal.
	Worn valve stem or valve guide.	Replace valve stem and guide.
	Leaking oil.	Repair oil leakage.
	Worn piston rings.	Replace piston rings.
	Plugged PCV system.	Service PCV system.

Condition	Possible Source	Action
Engine Noise	Excessive main bearing oil clearance.	Adjust clearance or replace main bearing.
	Seized or heat damaged main bearing.	Replace main bearing.
	Excessive crankshaft end play.	Replace crankshaft thrust main bearing.
	Excessive connecting rod bearing oil clearance.	Replace connecting rod.
	Heat damaged connecting rod bearing.	Replace connecting rod bearing.
	Damaged connecting rod bushing.	Replace connecting rod bushing.
	Worn cylinder.	Repair or replace cylinder blocks.
	Worn piston or piston pin.	Replace piston or piston pin.
	Damaged piston rings.	Replace piston rings.
	Bent connecting rod.	Replace connecting rod.
	Malfunctioning hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster.
	Excessive hydraulic lash adjuster or hydraulic lash adjuster clearance.	Adjust clearance or replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Broken valve spring.	Replace valve spring.
	Excessive valve guide clearance.	Repair clearance or replace valve guide/stem.
	Malfunctioning or damaged cooling system.	Refer to Section 05.
	Malfunctioning or damaged fuel system.	Refer to Section 04.
	Leaking exhaust system.	Repair exhaust leakage.
	Improper drive belt tension.	Refer to Section 05.
	Malfunctioning generator bearing.	Refer to Section 06 for diagnosis and testing of the generator.
	Loose timing chain/belt.	Adjust or replace timing chain/belt.
	Damaged timing belt tensioner.	Replace timing belt tensioner.
	Malfunctioning water pump bearing.	Replace water pump.
Insufficient Power	Malfunctioning hydraulic lash adjuster or hydraulic lash adjuster.	Replace hydraulic lash adjuster or hydraulic lash adjuster.
	Damaged hydraulic lash adjuster guide or hydraulic lash adjuster.	Replace hydraulic lash adjuster guide or hydraulic lash adjuster.
	Compression leakage at valve seat.	Repair or replace valve, valve seat or cylinder head.
	Seized valve stem.	Replace valve stem.
	Weak or broken valve spring.	Replace valve spring.
	Damaged cylinder head gasket.	Replace cylinder head gasket.
	Cracked or distorted cylinder head.	Replace cylinder head.
	Damaged, worn or sticking piston ring(s).	Repair or replace piston ring(s).
	Worn or damaged piston.	Replace piston.
	Malfunctioning or damaged fuel system.	Refer to Section 04.
	Malfunctioning or damaged ignition system.	Refer to Section 03.
	Damaged or plugged exhaust system.	Repair or replace exhaust system.

PCV System Malfunction

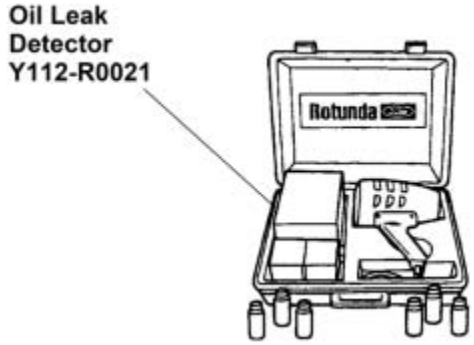
A malfunctioning Positive Crankcase Ventilation System (closed type) may be indicated by loping or rough engine idle. Do not attempt to compensate for this idle condition by disconnecting the PCV system and making an air bypass or idle speed adjustment.

CAUTION: The removal of the PCV system from the engine will adversely affect fuel economy and engine crankcase ventilation with resultant shortening of engine life.

Engine Oil Leaks

NOTE: When diagnosing engine oil leaks, the source and location of the leak must be positively identified prior to service.

Prior to performing this procedure, clean the cylinder block, cylinder heads, valve covers, oil pan and flywheel with a suitable solvent to remove all traces of oil.



Fluorescent Oil Additive Method

Use a 12 Volt Master UV Diagnostic Inspection Kit, such as the Rotunda Oil Leak Detector Y112-R0021 or equivalent, to perform the following procedure for oil leak diagnosis.

1. Clean the engine with a suitable solvent to remove all traces of oil.
2. Drain engine oil crankcase and refill with recommended oil, premixed with Diesel Engine Oil Dye 164-R3705 meeting Ford specification ESEM9C103- B1 or equivalent. Use a minimum 14.8 ml (0.5 ounce) to a maximum 29.6 ml (1 ounce) of fluorescent additive to all engines. If the oil is not premixed, fluorescent additive must first be added to crankcase.
3. Run the engine for 15 minutes. Stop the engine and inspect all seal and gasket areas for leaks using the 12 Volt Master UV diagnostic Inspection Kit. A clear bright yellow or orange area will identify the leak. For extremely small leaks, several hours may be required for the leak to appear.
4. If necessary, pressurize the main oil gallery system to locate leaks due to improperly sealed, loose or cocked plugs.
5. Repair all leaks as required.

Pressure Method

The crankcase can be pressurized to locate oil leaks. The following materials are required to fabricate the tool to be used:

- air supply and air hose
- air pressure gauge that registers pressure in 4 kPa (1 psi) increments
- airline shutoff valve
- appropriate fittings to attach the above parts to oil fill, PCV grommet hole and crankcase ventilation tube
- appropriate plugs to seal any openings leading to the crankcase
- a solution of liquid detergent and water to be applied with a suitable applicator such as a squirt bottle or brush

Fabricate the air supply hose to include the airline shutoff valve and the appropriate adapter to permit the air to enter the engine through the crankcase ventilation tube. Fabricate the air pressure gauge to a suitable adapter for installation on the engine at the oil filler opening.

CAUTION: Use extreme caution when pressurizing crankcase. Applying air pressure above specified pressure risks damage to seals, gaskets and core plugs. Under no circumstances should pressure be allowed to exceed 27 kPa (4 psi)

Testing Procedure

- Open the air supply valve until the pressure gauge maintains 20 kPa (3 psi).
- Inspect sealed or gasketed areas for leaks by applying a solution of liquid detergent and water over areas for formation of bubbles which indicates leakage.

Leakage Points - Above Engine

Examine the following areas for oil leakage.

- valve cover gaskets
- intake manifold gaskets
- cylinder head gaskets
- oil filter
- oil pump (if external)
- oil level indicator tube connection
- oil pressure sensor

Leakage Points - Under Engine

- oil pan gaskets
- oil pan sealer
- oil pan rear seal
- engine front cover gasket

- crankshaft front seal
- crankshaft rear oil seal

Leakage Points - with Flywheel Removed

NOTE: Air leakage in the area around a crankshaft rear oil seal does not necessarily indicate a crankshaft rear oil seal leak. However, if no other cause can be found for oil leakage, assume that the crankshaft rear oil seal is the cause of the oil leak.

NOTE: Light foaming equally around valve cover bolts and crankshaft seals is not detrimental; no repairs are required.

- rear main bearing cap and seals
- flywheel mounting bolt holes (with flywheel installed)
- camshaft rear bearing covers or pipe plugs at the end of oil passages (except for overhead cam)

Oil leaks at crimped seams in sheet metal parts and cracks in cast or stamped parts can be detected when pressurizing the crankcase.

Compression Tests

Compression Gauge Check

1. Make sure the oil in the crankcase is of the correct viscosity and at the proper level and that the battery is properly charged. Operate until the engine is at normal operating temperature. Turn the ignition switch to the OFF position, then remove all the spark plugs.
2. Set the throttle plates in the wide-open position.
3. Install a Compression Tester such as Rotunda Compression Tester 059-R0009, or equivalent, in the No. 1 cylinder.
4. Install an auxiliary starter switch in the starting circuit. With the ignition switch in the OFF position, and using the auxiliary starter switch, crank the engine a minimum of five compression strokes and record the highest reading. Note the approximate number of compression strokes required to obtain the highest reading.
5. Repeat the test on each cylinder, cranking the engine approximately the same number of compression strokes.

Test Results

The indicated compression pressures are considered within specification if the lowest reading cylinder is within 75 percent of the highest reading. Refer to the Compression Pressure Limit Chart.

If one or more cylinders reads low, squirt approximately one tablespoon of clean engine oil meeting Ford specification ESE-M2C153-E on top of the pistons in the low-reading cylinders. Repeat the compression pressure check on these cylinders.

Example Readings

If, after checking the compression pressures in all cylinders, it was found that the highest reading obtained was 1351 kPa (196 psi), and the lowest pressure reading was 1069 kPa (155 psi), the engine is within specification and the compression is considered satisfactory.

Compression Pressure Limit Chart

MAX-MIN kPa (psi)	MAX-MIN kPa (psi)	MAX-MIN kPa (psi)	MAX-MIN kPa (psi)
924 - 696 (134 - 101)	1131 - 848 (164 - 123)	1338 - 1000 (194 - 146)	1154 - 1158 (224 - 168)
938 - 703 (136 - 102)	1145 - 855 (166 - 124)	1351 - 1014 (196 - 147)	1558 - 1165 (226 - 169)
952 - 717 (138 - 104)	1158 - 869 (168 - 126)	1365 - 1020 (198 - 148)	1572 - 1179 (228 - 171)
965 - 724 (140 - 106)	1172 - 876 (170 - 127)	1379 - 1034 (200 - 150)	1586 - 1186 (230 - 172)
979 - 738 (142 - 107)	1186 - 889 (172 - 129)	1303 - 1041 (202 - 151)	1600 - 1200 (232 - 174)
933 - 745 (144 - 109)	1200 - 903 (174 - 131)	1407 - 1055 (204 - 153)	1055 - 1207 (153 - 175)
1007 - 758 (146 - 110)	1214 - 910 (176 - 132)	1420 - 1062 (206 - 154)	1627 - 1220 (154 - 177)
1020 - 765 (148 - 111)	1227 - 917 (178 - 133)	1434 - 1075 (208 - 156)	1641 - 1227 (238 - 178)
1034 - 779 (150 - 113)	1241 - 931 (180 - 135)	1448 - 1083 (210 - 157)	1655 - 1241 (240 - 180)
1048 - 786 (152 - 114)	1225 - 936 (182 - 136)	1462 - 1089 (212 - 158)	1669 - 1248 (242 - 181)
1062 - 793 (154 - 115)	1269 - 952 (184 - 138)	1476 - 1103 (214 - 160)	1682 - 1262 (244 - 183)
1076 - 807 (156 - 117)	1282 - 965 (186 - 140)	1489 - 1117 (216 - 162)	1696 - 1269 (246 - 184)
1089 - 814 (158 - 118)	1296 - 972 (188 - 141)	1503 - 1124 (218 - 163)	1710 - 1202 (248 - 186)
1103 - 872 (160 - 120)	1310 - 979 (190 - 142)	1517 - 1138 (220 - 165)	1724 - 1289 (250 - 187)
1110 - 834 (161 - 121)	1324 - 993 (192 - 144)	1631 - 1145 (222 - 166)	

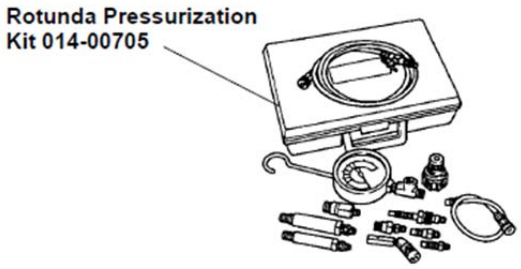
Interpreting Compression Readings

1. If compression improves considerably, with the addition of oil, piston rings are faulty.
2. If compression does not improve with oil, valves are sticking or seating improperly.
3. If two adjacent cylinders indicate low compression pressures and squirting oil on each piston does not increase compression, the head gasket may be leaking between cylinders. Engine oil or coolant in cylinders could result from this condition.

Use the Compression Pressure Limit Chart when checking cylinder compression so that the lowest reading is within 75 percent of the highest reading.

Cylinder Leakage Detection

When a cylinder produces a low reading, use of the Engine Cylinder Leak Detection/Air Pressurization Kit, such as the Rotunda Pressurization Kit 014-00705, or equivalent, will be helpful in pinpointing the exact cause.



The leakage detector is inserted in the spark plug hole, the piston is brought up to dead center on the compression stroke, and compressed air is admitted.

Once the combustion chamber is pressurized, a special gauge included in the kit will read the percentage of leakage. Leakage exceeding 20 percent is excessive.

While the air pressure is retained in the cylinder, listen for the hiss of escaping air. A leak at the intake valve will be heard in the throttle body. A leak at the exhaust valve can be heard at the tail pipe. Leakage past the piston rings will be audible at the positive crankcase ventilation (PCV) connection. If air is passing through a blown head gasket to an adjacent cylinder, the noise will be evident at the spark plug hole of the cylinder into which the air is leaking. Cracks in the cylinder blocks or gasket leakage into the cooling system may be detected by a stream of bubbles in the radiator.

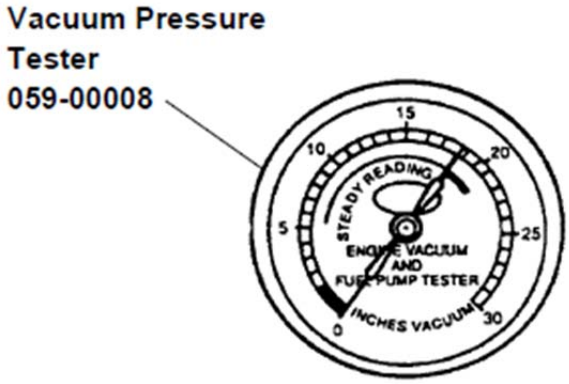
Oil Leak and Valve Stem Seal Test

The cylinder leakage detector tests for engine oil leaks and checks the valve stem seals for leakage.

1. Plug all crankcase openings except the one used for connecting the leakage detector.
2. Connect the Engine Cylinder Leak Detection/Air Pressurization Kit to a crankcase opening (an oil level indicator tube is convenient). Adjust the air pressure to approximately 34 kPa (5 psi).
3. Using a solution of liquid soap and water, brush the solution along the gasket sealing surfaces and bearing seals. Look for bubbles or foam.
4. Remove the spark plugs and rotate the crankshaft slowly with a wrench. Check for large amounts of air escaping into the cylinders as each intake valve and exhaust valve opens.
5. The spark plugs on the leaking cylinders will probably show deposits of burned oil.

Intake Manifold Vacuum Test

Bring the engine to normal operating temperature. Connect a Vacuum/Pressure Tester, such as Rotunda Vacuum/Pressure Tester 059-00008 or equivalent, to the intake manifold. Run the engine at the specified idle speed.



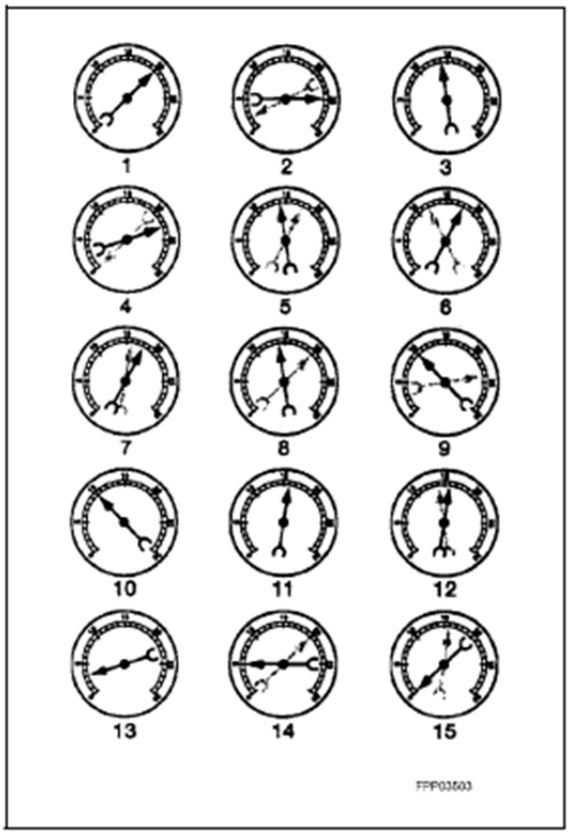
The vacuum gauge should read between 51-74 kPa (15-22 in-Hg) depending upon the engine condition and the altitude at which the test is performed. Subtract 5.5 kPa (1 in-Hg) from the specified reading for every 500 meters (1,000 feet) of elevation above sea level.

The reading should be quite steady. If necessary, adjust the gauge damper control (where used) if the needle is fluttering rapidly. Adjust the damper until the needle moves easily without excessive flutter.

Interpreting Vacuum Gauge Readings
A careful study of the vacuum gauge reading while the engine is idling will help pinpoint trouble areas. Always conduct other appropriate tests before arriving at a final diagnostic decision. Vacuum gauge readings, although helpful, must be interpreted carefully.

Most vacuum gauges have a normal band indicated on the gauge face.

The following are potential gauge readings. Some are normal; others should be investigated further.



1. NORMAL READING: Needle between 51-74 kPa (15-22 in-Hg) and holding steady.
2. NORMAL READING DURING RAPID ACCELERATION AND DEACCELERATION: When the engine is rapidly accelerated (dotted needle), the needle will drop to a low reading (not to zero). When the throttle is suddenly released, the needle will snap back up to a higher than normal figure.
3. NORMAL FOR HIGH-LIFT CAMSHAFT WITH LARGE OVERLAP: The needle will register as low as 51 kPa (15 in-Hg) but will be relatively steady. Some oscillation is normal.
4. WORN RINGS OR DILUTED OIL: When the engine is accelerated (dotted needle), the needle drops to 0 kPa (0 in-Hg). Upon deceleration, the needle runs slightly above 74 kPa (22 in-Hg).
5. STICKING VALVES: When the needle (dotted) remains steady at a normal vacuum but occasionally flicks (sharp, fast movement) down and back about 13 kPa (4 in-Hg), one or more valves may be sticking.
6. BURNED OR WARPED VALVES: A regular, evenly spaced, downscale flicking of the needle indicates one or more burned or warped valves. Insufficient hydraulic lash adjuster or hydraulic lash adjuster (HLA) clearance will also cause this reaction.
7. POOR VALVE SEATING: A small but regular downscale flicking can mean one or more valves are not seating.
8. WORN VALVE GUIDES: When the needle oscillates (swings back and forth) over about a 13 kPa (4 in- Hg) range at idle speed, the valve guides could be worn. As engine speed increases, the needle will become steady if guides are responsible.
9. WEAK VALVE SPRINGS: When the needle oscillation becomes more violent as engine rpm is increased, weak valve springs are indicated. The reading at idle could be relatively steady.
10. LATE VALVE TIMING: A steady but low reading could be caused by late valve timing.
11. IGNITION TIMING RETARDING: Retarded ignition timing will produce a steady but somewhat low reading.
12. INSUFFICIENT SPARK PLUG GAP: When spark plugs are gapped too close, a regular, small pulsation of the needle can occur.
13. INTAKE LEAK: A low, steady reading can be caused by an intake manifold or throttle body gasket leak.
14. BLOWN HEAD GASKET: A regular drop of approx. 33-50 kPa (10-15 in-Hg) can be caused by a blown head gasket or warped cylinder head-to-cylinder block surface.
15. RESTRICTED EXHAUST SYSTEM: When the engine is first started and is idled, the reading may be normal, but as the engine rpm is increased, the back pressure caused by a clogged muffler, kinked tail pipe or other concerns will cause the needle to slowly drop to 0 kPa (0 in-Hg). The needle then may slowly rise. Excessive exhaust clogging will cause the needle to drop to a low point even if the engine is only idling.

When vacuum leaks are indicated, search out and correct the cause. Excess air leaking into the system will upset the fuel mixture and cause concerns such as rough idle, missing on acceleration or burned valves. If the leak exists in an accessory unit such as the power brake booster, the unit will not function correctly. Always fix vacuum leaks.

Excessive Engine Oil Consumption

The amount of oil an engine uses will vary with the way the equipment is driven in addition to normal engine to engine variation. This is especially true during the first 340 hours or 16,100 km (10,000 miles) when a new engine is being broken in or until certain internal engine components become conditioned. Engines used in heavy-duty operation may use more oil. The following are examples of heavy-duty operation:

- severe loading applications
- sustained high speed operation

Engines need oil to lubricate the following internal components:

- cylinder block, cylinder walls
- pistons, piston pins and rings
- intake and exhaust valve stems
- intake and exhaust valve guides
- all internal engine components

When the pistons move downward, a thin film of oil is left on the cylinder walls. As the engine is operated, some oil is also drawn into the combustion chambers past the intake and exhaust valve stem seals and burned.

The following is a partial list of conditions that can affect oil consumption rates:

- engine size
- operator driving habits
- ambient temperature
- quality and viscosity of the oil

Operating under varying conditions can frequently be misleading. An engine that has been run for short hours or in below-freezing ambient temperatures may have consumed a “normal” amount of oil.

However, when checking engine oil level, it may measure up to the full mark on the oil level dipstick due to dilution (condensation and fuel) in the engine crankcase. The engine might then be run at high speeds where the condensation and fuel boil off. The next time the engine oil is checked, it may appear that a liter (quart) of oil was used in about 3 to 3-1/2 hours.

This perceived 3 to 3-1/2 hours per liter (quart) oil consumption rate causes customer concern even though the actual overall oil consumption rate is about 50 hours per liter (quart).

Make sure the selected engine oil meets Ford specification WSS-M2C153-F and the recommended API performance category “SJ” or higher and SAE viscosity grade as shown in the equipment Owner’s or Operators Engine handbook. It is also important that the engine oil is changed at the intervals specified. Refer to the Engine Operator’s handbook.

Oil Consumption Test

The following diagnostic procedure is used to determine the source of excessive internal oil consumption.

NOTE: Oil use is normally greater during the first 300 hours of service. As hours increase, oil use generally decreases. Engines in normal service should get at least 31.7 hours per quart (900 miles per quart) after 300 hours of service. High speeds, heavy loads, high ambient temperature and other factors may result in greater oil use.

1. Determine customer’s engine load habits, such as sustained high speed operation, extended idle, heavy work loads and other considerations.
2. Verify that the engine has no external oil leak as described under Engine Oil Leaks in the Diagnosis and Testing portion of this section.
3. Verify that the engine has the correct oil level dipstick.
4. Verify that the engine is not being run in an overfilled condition. Check the oil level at least five minutes after a hot shutdown with the engine/vehicle parked on a level surface. In no case should the level be above the top of the cross-hatched area and the letter F in FULL. If significantly overfilled, perform= steps 5 through 9. If not proceed to step 10.
5. Drain the engine oil, remove and replace the oil filter and refill with one quart less than the recommended amount.
6. Run the engine for three minutes (10 minutes if cold), and allow the oil to drain back for at least five minutes with the engine/vehicle on a level surface.
7. Remove oil level dipstick and wipe clean.

CAUTION: Do not wipe with anything contaminated with silicone compounds.

8. Reinstall the oil level dipstick, being sure to seat it firmly in the oil level indicator tube. Remove the oil level dipstick and draw a mark on the back (unmarked) surface at the indicated oil level. This level should be about the same as the ADD mark on the face of the oil level dipstick.
9. Add one quart of oil. Restart the engine and allow to idle for at least two minutes. Shut off the engine and allow the oil to drain back for at least five minutes. Mark the oil level dipstick, using the procedure above. This level may range from slightly below the top of the cross-hatched area to slightly below the letter F in FULL.

10. Record the vehicle mileage or hours.

11. Instruct the customer to run engine as usual and perform the following:
    - Check the oil level regularly at intervals of 3 to 3-1/2 hours.
    - Return to the service point when the oil level drops below the lower (ADD) mark on the oil level dipstick.
    - Add only full quarts of the same oil in an emergency. Note the mileage at which the oil is added.
12. Check the oil level under the same conditions and at the same location as in Steps 7-9
    - Measure the distance from the oil level to the UPPER mark on the oil level dipstick and record.
    - Measure the distance between the two scribe marks and record.
    - Divide the first measurement by the second.
    - Divide the hours run during the oil test by the result. This quantity is the approximate oil consumption rate in hours per quart.
13. If the oil consumption rate is unacceptable, proceed to next step.
14. Check the positive crankcase ventilation (PCV) system. Make sure the system is not plugged.
15. Check for plugged oil drain-back holes in the cylinder heads and cylinder blocks.
16. If the condition still exists after performing the above steps, proceed to next step.
17. Perform a cylinder compression test – Refer to “Compression Tests” on page 12 or perform a cylinder leak detection test with Engine Cylinder Leak Detection/Air Pressurization Kit – Refer to “Cylinder Leakage Detection” on page 13. This can help determine the source of oil consumption such as valves, piston rings or other areas.

NOTE: After determining if worn parts should be replaced, make sure correct replacement parts are used.

18. Check valve guides for excessive guide clearances. REPLACE all valve stem seals after verifying valve guide clearance.
19. Worn or damaged internal engine components can cause excessive oil consumption. Small deposits of oil on the tips of spark plugs can be a clue to internal oil consumption. If internal oil consumption still persists, proceed as follows:
    - Remove the engine from the vehicle and place it on an engine work stand. Remove the intake manifolds, cylinder heads, oil pan and oil pump.
    - Check piston ring clearance, ring gap and ring orientation. Repair as required.
    - Check for excessive bearing clearance. Repair as required.
20. Perform the oil consumption test to confirm the oil consumption concern has been resolved.

Oil Pressure Test

1. Disconnect and remove the oil pressure sensor from the engine.
2. Connect the Engine Oil Pressure Gauge and Transmission Test Adapter to the oil pressure sender oil gallery port.
3. Run the engine until normal operating temperature is reached.
4. Run the engine at 3000 rpm and record the gauge reading.
5. The oil pressure should be within specifications.
6. If the pressure is not within specification, check the following possible sources:
    - insufficient oil
    - oil leakage
    - worn or damaged oil pump
    - oil pump screen cover and tube
    - excessive main bearing clearance
    - excessive connecting rod bearing clearance

Valve Train Analysis – Static

With engine off and valve cover removed, check for damaged or severely worn parts and correct assembly. Make sure correct parts are used with the static engine analysis as follows.

Rocker Arm

- Check for loose mounting bolts, studs and nuts.
- Check for plugged oil feed in the rocker arms or cylinder head.

Camshaft Roller Followers and Hydraulic Lash Adjusters

- Check for loose mounting bolts on camshaft carriers.
- Check for plugged oil feed in the camshaft roller followers, hydraulic lash adjusters (HLA) or cylinder heads.

Camshaft

- Check for broken or damaged parts.
- Check the bolts on the intake manifold.

Push Rods (if equipped)

- Check for bent push rods and restricted oil passage.

Valve Springs

- Check for broken or damaged parts.

Valve Spring Retainer and Valve Spring Retainer Keys

- Check for proper seating of the valve spring retainer key on the valve stem and in valve spring retainer.

Valve Spring Retainer Keys

- Check for proper seating on the valve stem.

Valves and Cylinder Head

- Check the head gasket for proper installation.
- Check for plugged oil drain back holes.
- Check for worn or damaged valve tips.
- Check for missing or damaged guide-mounted valve stem seal.
- Check collapsed lash adjuster gap.
- Check installed valve spring height.
- Check for missing or worn valve spring seats.
- Check for plugged oil metering orifice in cylinder head oil reservoir (if equipped).

Static checks (engine off) are to be made on the engine prior to the dynamic procedure.

Valve Train Analysis – Dynamic

Start the engine and, while idling, check for proper operation of all parts. Check the following:

Rocker Arm

- Check for plugged oil in the rocker arms or cylinder head.
- Check for proper overhead valve train lubrication.

If insufficient oiling is suspected, accelerate the engine to 1200 rpm ± 100 rpm with the PTO in NEUTRAL or load removed and the engine at normal operating temperature. Oil should spurt from the rocker arm oil holes such that valve tips and rocker arms are well oiled or, with the valve covers off, oil splash may overshoot the rocker arms. If oiling is insufficient for this to occur, check oil passages for blockage.

Push Rods (if equipped)

- Check for bent push rods and restriction in oil passage.

Positive Rotator and Valve Spring Retainer Keys

- Check for proper operation of positive rotator.

Valves and Cylinder Head

- Check for plugged oil drain back holes.
- Check for missing or damaged valve stem seals or guide mounted valve stem seals.

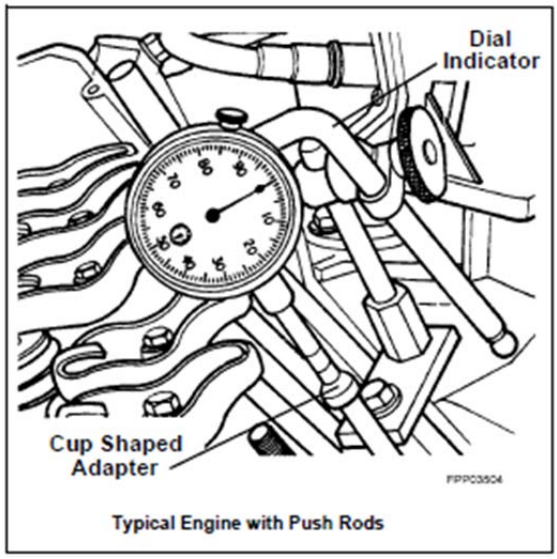
If insufficient oiling is suspected, check oil passages for blockage, then accelerate the engine to 1200 rpm with the PTO in NEUTRAL or load removed and the engine at normal operating temperature. Oil should spurt from the rocker arm oil holes such that valve tips and camshaft roller followers are well oiled. With the valve covers off, some oil splash may overshoot camshaft roller followers.

Camshaft Lobe Lift

Check the lift of each lobe in consecutive order and make a note of the readings.

1. Remove the valve covers.

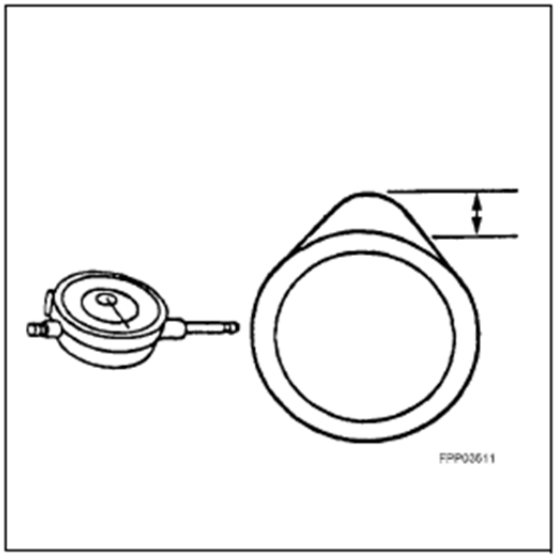
2. Remove the rocker arm seat bolts, rocker arm seat and rocker arms (if equipped).



Typical Engine with Push Rods

3. Make sure the lash adjuster is seated against camshaft. Install the dial Indicator with Bracketry so the ball socket adapter of the indicator is on top of the hydraulic lash adjuster or the Cup Shaped Adapter is on top of the push rod and in the same plane as the lash adjuster push rod movement.

4. On engines with overhead cam, install the dial Indicator with Bracketry so the plunger is on top of the camshaft lobe and in the same plane as the camshaft lobe movement.



5. Remove the spark plugs.

6. Connect an auxiliary starter switch in the starting circuit. Crank the engine with the ignition switch in the OFF position. Bump the crankshaft over until the indicator is measuring on the base circle of the camshaft lobe (in its lowest position). If checking during engine assembly, turn the crankshaft using socket or ratchet.

7. Zero the dial indicator. Continue to rotate the crankshaft slowly until the camshaft lobe is in the fully-raised position (highest indicator reading).

NOTE: If the lift on any lobe is below specified service limits, the camshaft and any component operating on worn lobes must be replaced.

8. Compare the total lift recorded on the dial indicator with specifications.

9. To check the accuracy of the original dial indicator reading, continue to rotate the crankshaft until the indicator reads zero.

10. Remove the dial indicator, adapter and auxiliary starter switch.

11. Reinstall components as necessary.

CAUTION: Do not rotate the crankshaft until lash adjusters have had sufficient time to bleed down. To do otherwise may cause serious valve damage. Manually bleeding-down lash adjusters will reduce waiting time.

Hydraulic Valve Lash Adjuster

Hydraulic lash adjuster noise can be caused by any of the following:

- excessively collapsed lash adjuster gap
- sticking lash adjuster plunger
- lash adjuster check valve not functioning properly
- air in lubrication system
- leak down rate too rapid
- excessive valve guide wear

Excessive collapsed lash adjuster gap can be caused by loose rocker arm seat bolts/nuts, incorrect initial adjustment or wear of lash adjuster face, or worn roller lash adjusters, push rod, rocker arm, rocker arm seat or valve tip. With lash adjuster collapsed, check gap between the valve tip and the rocker arm to determine if any other valve train parts are damaged, worn or out of adjustment.

A sticking lash adjuster plunger can be caused by dirt, chips or varnish inside the lash adjuster.

A lash adjuster check valve that is not functioning can be caused by an obstruction such as dirt or chips that prevent it from closing when the camshaft lobe is lifting the lash adjuster. It may also be caused by a broken check valve spring.

Air bubbles in the lubrication system will prevent the lash adjuster from supporting the valve spring load. This can be caused by too high or too low an oil level in the oil pan or by air being drawn into the system through a hole, crack or leaking gasket on the oil pump screen cover and tube.

If the leak down time is below the specified time for used lash adjusters, noisy operation can result. If no other cause for noisy lash adjusters can be found, the leak down rate should be checked and any lash adjusters outside the specification should be replaced.

Assembled lash adjusters can be tested with Hydraulic lash adjuster Leak down Tester to check the leak down rate. The leak down rate specification is the time in seconds for the plunger to move a specified distance while under a 22.7 kg (50 lb.) load. Test the lash adjusters as follows:

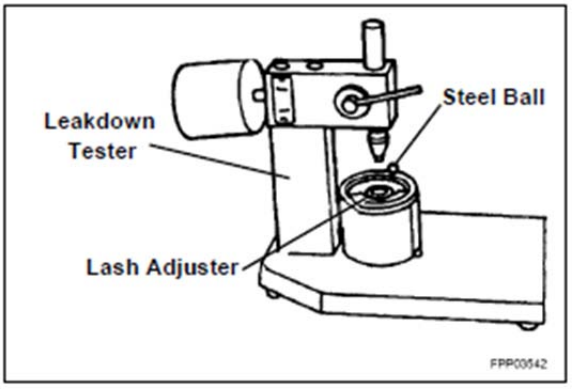
Leak down Testing

NOTE: Do not mix parts from different hydraulic lash adjusters. Parts are select-fit and are not interchangeable.

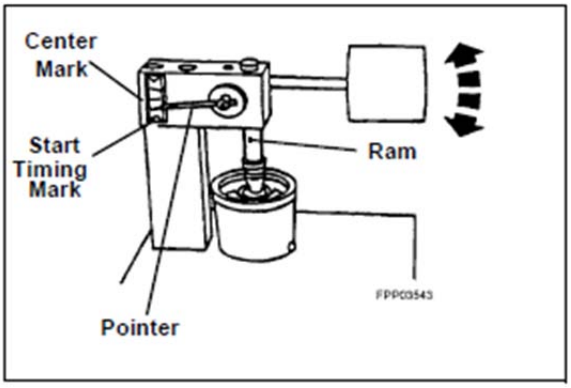
1. Clean the lash adjuster to remove all traces of engine oil.

NOTE: Lash adjusters cannot be checked with engine oil in them. Use only testing fluid. New hydraulic lash adjusters are already filled with testing fluid.

2. Place the lash adjuster in the tester with the plunger facing upward. Position the steel ball provided in the plunger cap. Add testing fluid to cover the hydraulic lash adjuster and compress Leak down Tester until the hydraulic lash adjuster is filled with testing fluid and all traces of air bubbles have disappeared. The fluid can be purchased from the tester's manufacturer. Using kerosene or any other fluid will not provide an accurate test.



3. Adjust the length of the ram so the pointer is just below the start timing mark when the ram contacts the hydraulic lash adjuster. Start Timing as the pointer passes the start timing mark and end timing as the pointer reaches the center mark.



4. A satisfactory lash adjuster must have a leak down rate (time in seconds) within specified minimum and maximum limits.
5. If the lash adjuster is not within specification, replace it with a new lash adjuster. Do not disassemble and clean new lash adjusters before testing because oil contained in the new lash adjuster is test fluid.
6. Remove the fluid from the cup and bleed the fluid from the lash adjuster by working the plunger up and down. This step will aid in depressing the lash adjuster plungers when checking valve clearance.

GENERAL SERVICE PROCEDURES

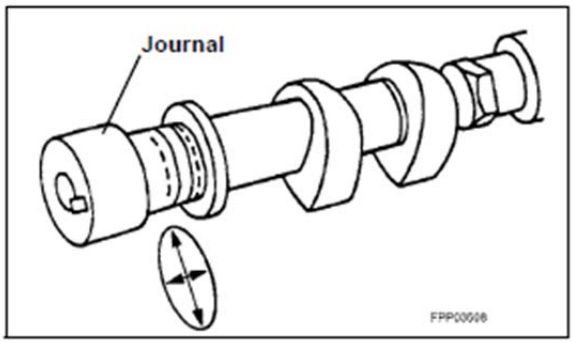
WARNING: TO AVOID THE POSSIBILITY OF PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT, DO NOT OPERATE THE ENGINE UNTIL THE FAN BLADE HAS BEEN EXAMINED FOR POSSIBLE CRACKS AND SEPARATION.

NOTE: Illustrations are typical and may not reflect your particular engine. Specifications show the expected minimum or maximum condition.

NOTE: If a component fails to meet the specifications, it is necessary to replace or refinish. If the component can be refinished, wear limits are provided as an aid to making a decision. Any component that fails to meet specifications and cannot be refinished must be replaced.

Camshaft Journal Diameter

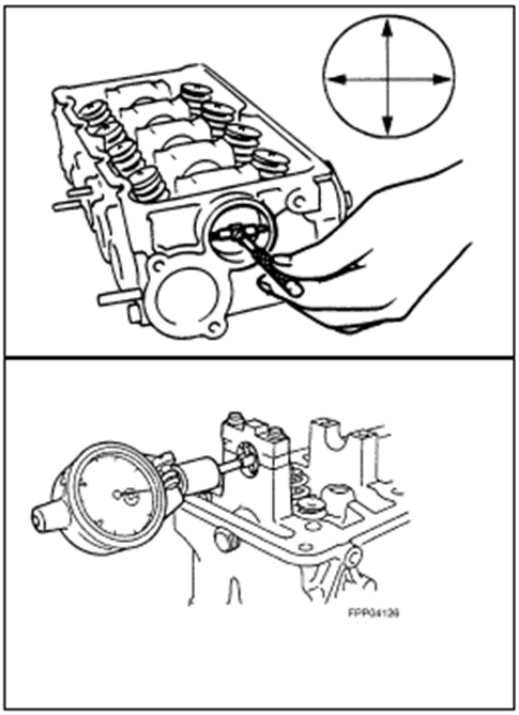
- Measure each camshaft journal diameter in two directions.
- If it is out of specification, replace as necessary.



Camshaft Journal Clearance

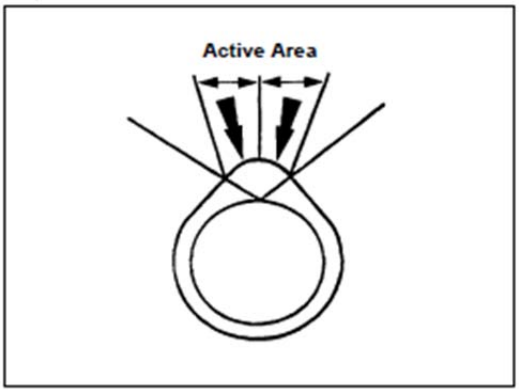
NOTE: The camshaft journals must meet specifications before checking camshaft journal clearance.

- Measure each camshaft bearing in two directions.
- Subtract the camshaft journal diameter from the camshaft bearing diameter



Camshaft Lobe Surface

- Inspect camshaft lobes for pitting or damage in the active area. Minor pitting is acceptable outside the active area

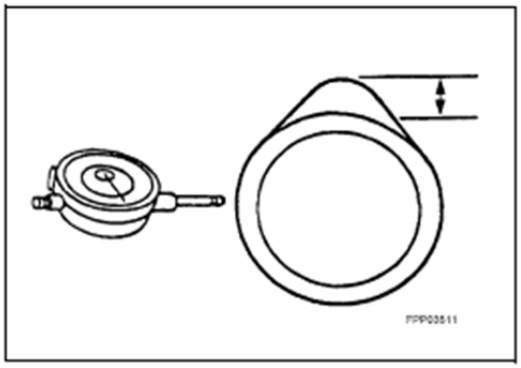


Camshaft Lobe Lift

Special Tool(s)

	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

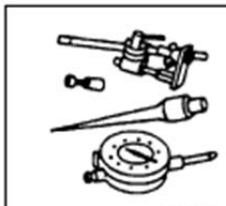
1. Use the Dial Indicator with Bracketry to measure camshaft intake lobe lift.



2. Rotate the camshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the camshaft lobe lift.
3. Use the Dial Indicator with Bracketry to measure camshaft exhaust lobe lift.
4. Rotate the camshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the camshaft lobe lift.

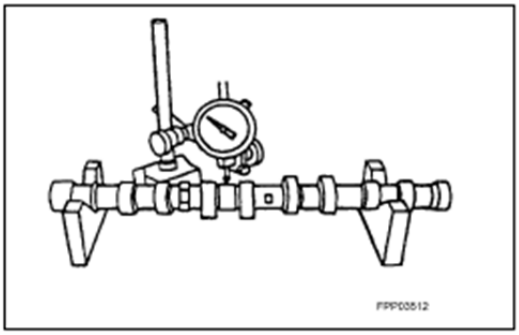
Camshaft Runout

Special Tool(s)

	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

NOTE: Camshaft journals must be within specifications before checking runout.

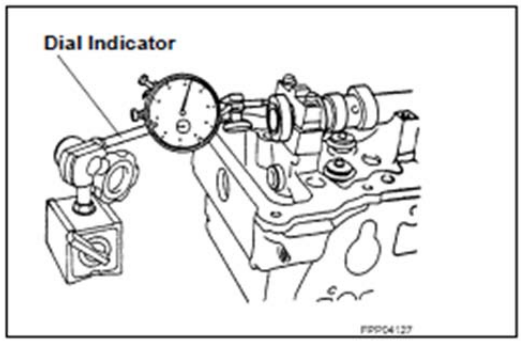
- Use the Dial Indicator with Bracketry to measure the camshaft runout.
- Rotate the camshaft and subtract the lowest dial indicator reading from the highest dial indicator reading.



Camshaft End Play

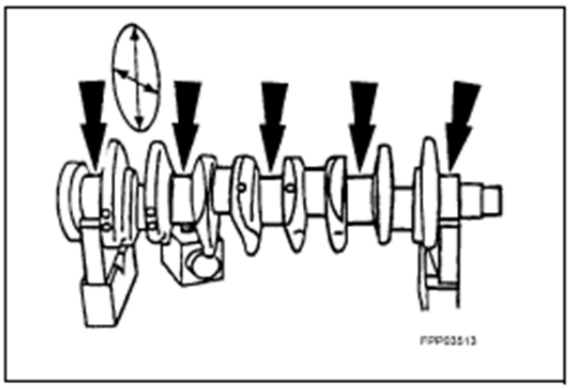
- Move camshaft to the rear.
- Zero dial indicator.
- Move camshaft to the front.
- Compare end play with specifications

.



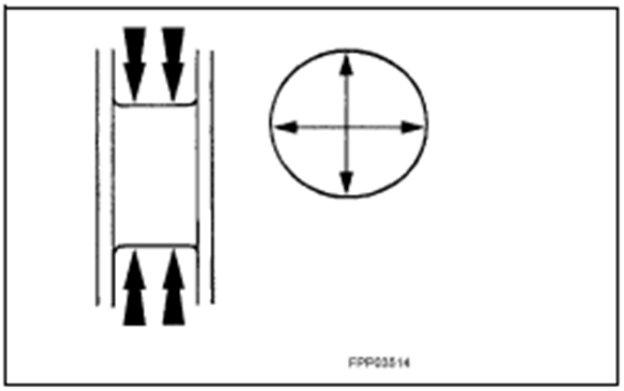
Crankshaft Main Bearing Journal Diameter

- Measure each of the crankshaft main bearing journal diameters in at least two directions.
- If it is out of specification, replace as necessary.



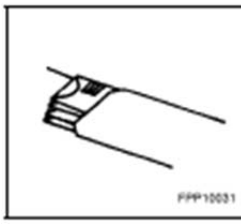
Crankshaft Main Bearing Journal Taper

- Measure each of the crankshaft main bearing journal diameters in at least two directions at each end of the main bearing journal.
- If it is out of specifications, replace as necessary.



Crankshaft Main Bearing Journal Clearance

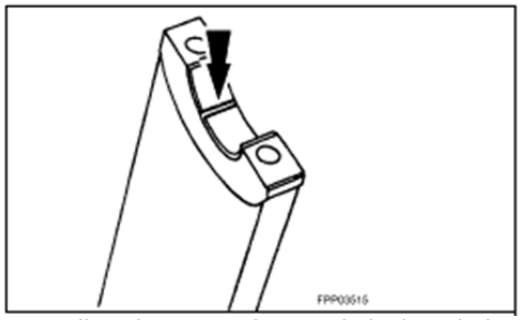
Special Tool(s)

	Plastigage® D81L-6002-B or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

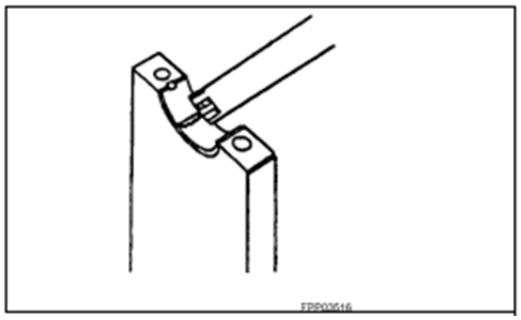
NOTE: Crankshaft main bearing journals must be within specifications before checking journal clearance.

1. Remove the crankshaft main bearing caps and bearings.
2. Lay a piece of Plastigage® across the face of each crankshaft main surface.

NOTE: Do not turn the crankshaft while doing this procedure.



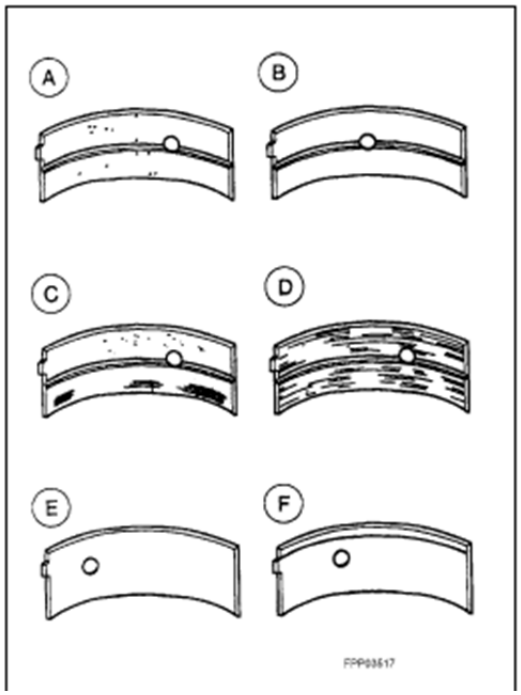
3. Install and remove the crankshaft main bearing cap.
4. Verify the crankshaft journal clearance.
   - If it is out of specification, replace as necessary



Bearing Inspection

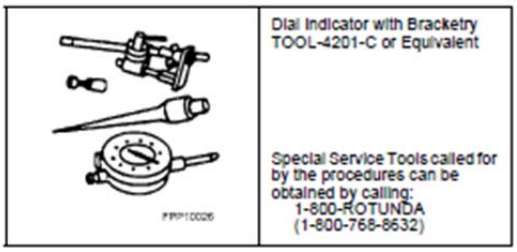
Inspect bearings for the following defects. Possible causes are shown:

- Cratering – fatigue failure (A)
- Spot polishing – improper seating (B)
- Scratching – dirty (C)
- Base exposed – poor lubrication (D)
- Both edges worn – journal damaged (E)
- One edge worn – journal tapered or bearing not seated (F)

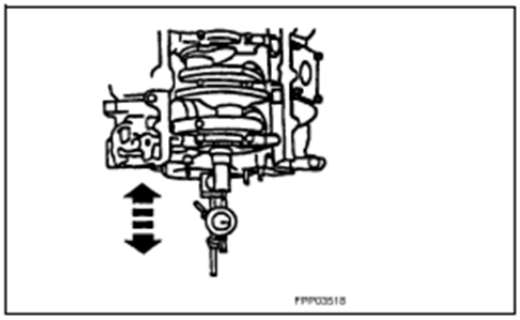


Crankshaft End Play

Special Tool(s)



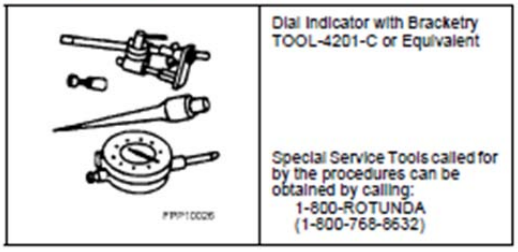
1. Measure the crankshaft end play. Use the Dial Indicator with Bracketry to measure crankshaft end play.
2. Position the crankshaft to the rear of the cylinder block.
3. Zero the Dial Indicator with Bracketry.



4. Move the crankshaft to the front of the cylinder block. Note and record the camshaft end play.
    - If camshaft end play exceeds specifications, replace the crankshaft thrust washers or thrust bearing.

‘’Crankshaft Runout

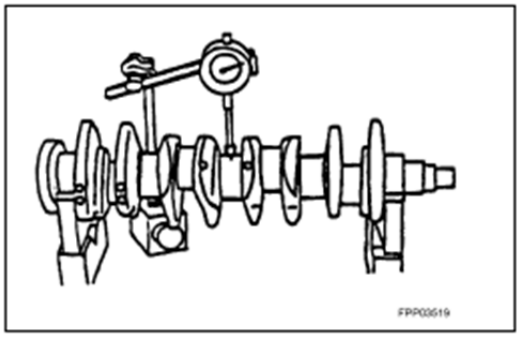
Special Tool(s)



NOTE: Crankshaft main bearing journals must be within specifications before checking runout.

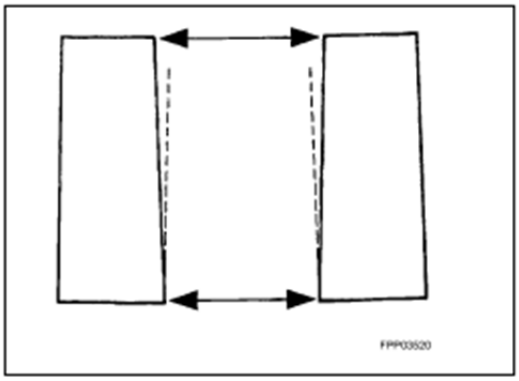
Use the Dial Indicator with Bracketry to measure the crankshaft runout.

- Rotate the crankshaft and subtract the lowest dial indicator reading from the highest dial indicator reading to figure the crankshaft runout. If it is out of specification, replace as necessary.



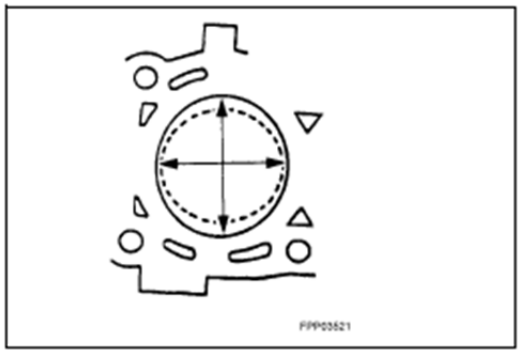
Cylinder Bore Taper

Measure the cylinder bore at the top and bottom. Verify the cylinder bore is within the wear limit. The difference indicates the cylinder bore taper. Bore the cylinder to the next oversize.



Cylinder Bore Out-of-Round

Measure the cylinder bore in two directions. The difference is the out-of-round. Verify the out-of-round I within the wear limit and bore the cylinder to the next oversize limit.



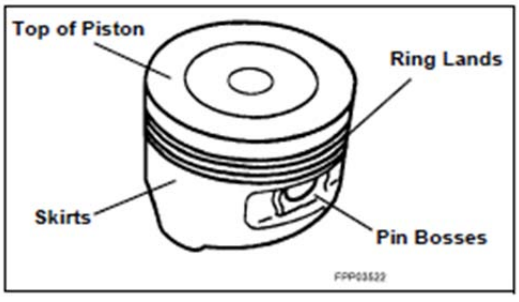
Piston Inspection

Special Tool(s)

FPP10032	Piston Ring Groove Cleaner D81L-6002-D or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

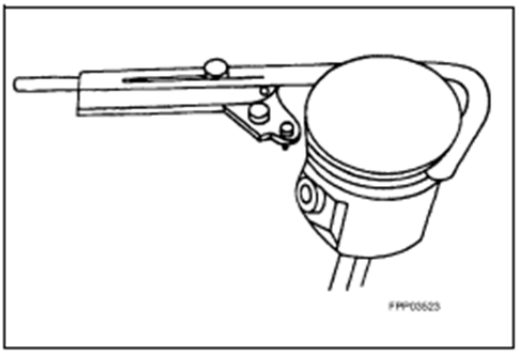
CAUTION: Do not use a caustic cleaning solution or a wire brush to clean the pistons or possible damage can occur.

1. Clean and inspect the ring lands, skirts, pin bosses, and the tops of the pistons. If wear marks or polishing is found on the piston skirt, check for a bent or twisted connecting rod.



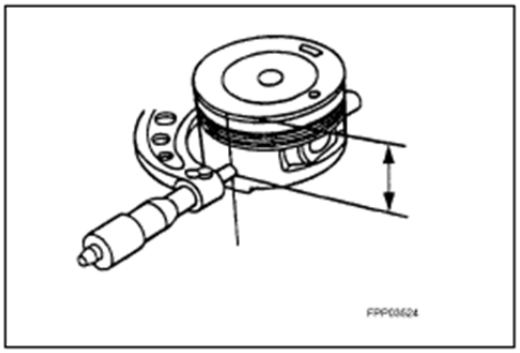
2. Use the Piston Ring Groove Cleaner to clean the piston ring grooves.

- Make sure the oil ring holes are clean.



Piston Diameter

- Measure the piston skirt diameter.



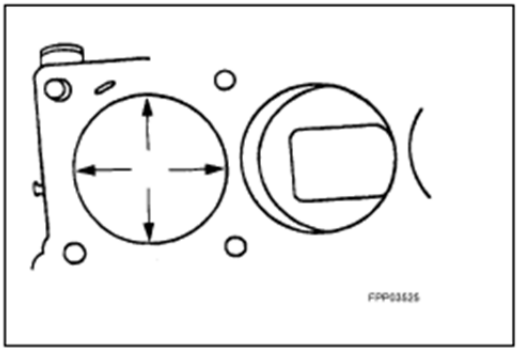
Piston to Cylinder Bore Clearance

Subtract the piston diameter from the cylinder bore diameter to find the piston-to-cylinder bore clearance.

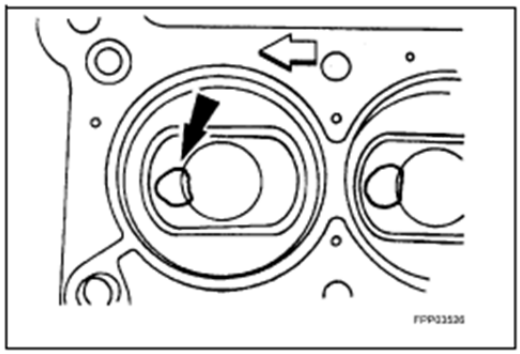
Piston Selection

NOTE: The cylinder bore must be within the specifications for taper and out-of-round before fitting a piston.

1. Select a piston size based on the cylinder bore.



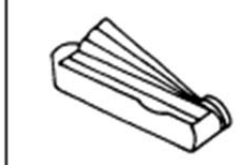
NOTE: For precision fit, new pistons are divided into three categories within each size range based on their relative position within the range. A paint spot on the new pistons indicates the position within the size range.



2. Choose the piston with the proper paint color.
    - Red – in the lower third of the size range.
    - Blue – in the middle third of the size range.
    - Yellow – in the upper third of the size range.

Piston Ring End Gap

Special Tool(s)

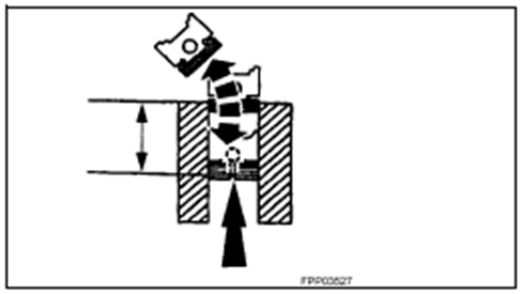
	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

CAUTION: Use care when fitting piston rings to avoid possible damage to the piston ring or the cylinder bore.

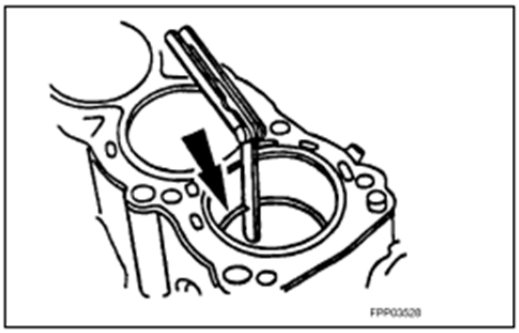
CAUTION: Piston rings should not be transferred from one piston to another to prevent damage to cylinder worn or piston.

NOTE: Cylinder bore must be within specification for taper and out-of-round to fit piston rings.

1. Use a piston without rings to push a piston ring in a cylinder to the bottom of ring travel.

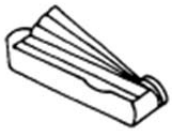


2. Use a feeler gauge to measure the top piston ring end gap and the second piston ring end gap.

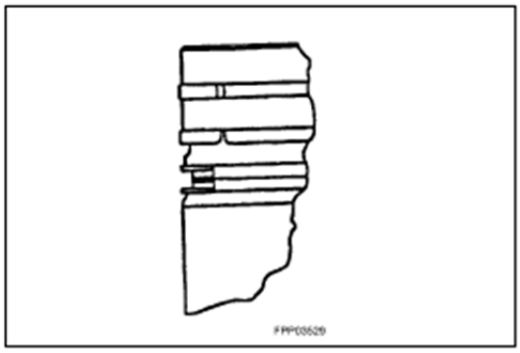


Piston Ring-to-Groove Clearance

Special Tool(s)

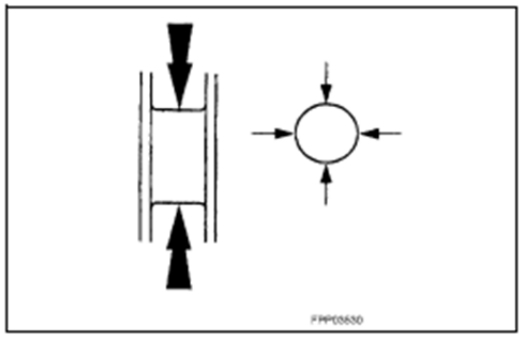
	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

1. Inspect for a stop in the grooves.
2. Measure the piston-to-groove clearance.



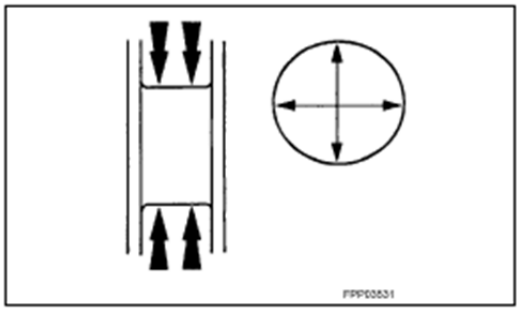
Crankshaft Connecting Rod Journal Diameter

- Measure the crankshaft connecting rod journal diameters in at least two directions perpendicular to one another. The difference between the measurements is the out-of-round. Verify the journal is within the wear limit specification.



Crankshaft Connecting Rod Journal Taper

- Measure the crankshaft rod journal diameters in two directions perpendicular to one another at each end of the connecting rod journal. The difference in the measurements from one end to the other is the taper. Verify measurement is within the wear limit.

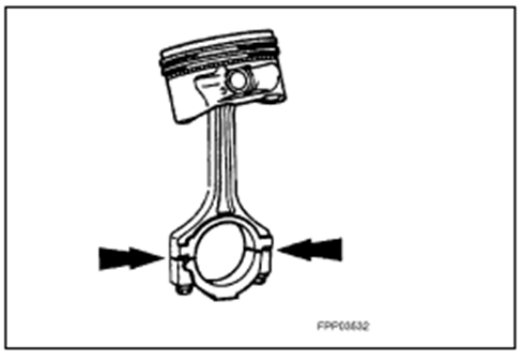


Connecting Rod Cleaning

CAUTION: Do not use a caustic cleaning solution or damage to connecting rods can occur.

NOTE: The connecting rod large end is mechanically split or cracked to produce a unique parting face. This produces a locking joint. Parts are not interchangeable.

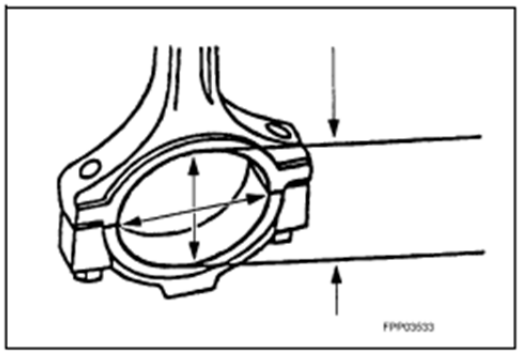
- Mark and separate the parts and clean with solvent. Clean the oil passages



Connecting Rod Larger End Bore

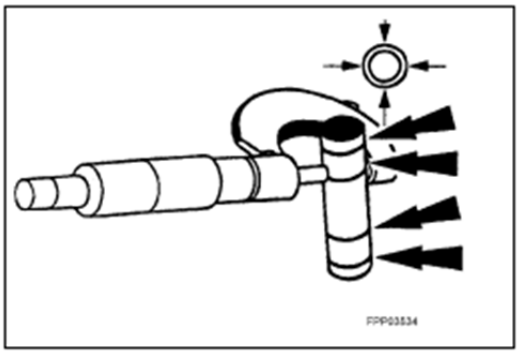
CAUTION: The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

- Measure the bore in two directions. The difference is the connecting rod bore out-of-round. Verify the out of- round is within specification.



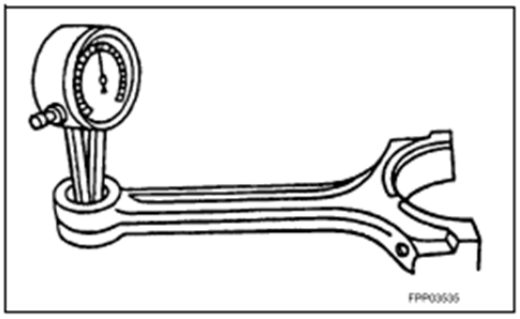
Piston Pin Diameter

- Measure the piston pin diameter in two directions at the points shown. Verify the diameter is within specifications.



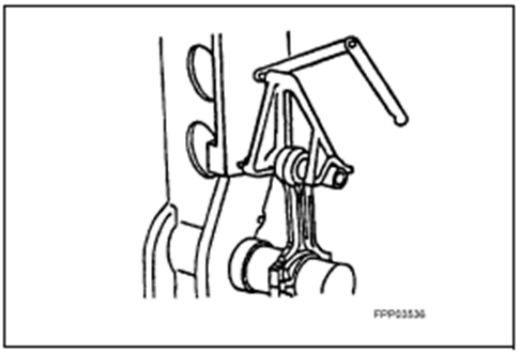
Connecting Rod Bushing Diameter

- Measure the inner diameter of the connecting rod bushing. Verify the diameter is within specification.



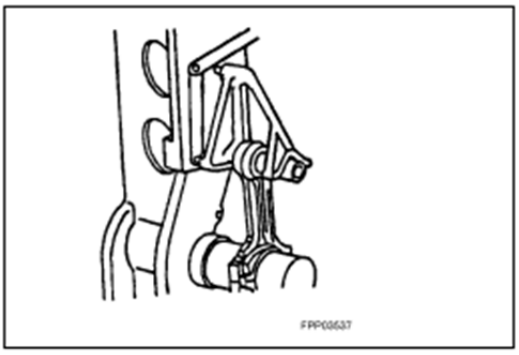
Connecting Rod Bend

- Measure the connecting rod bend on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. Verify the bend measurement is within specification.



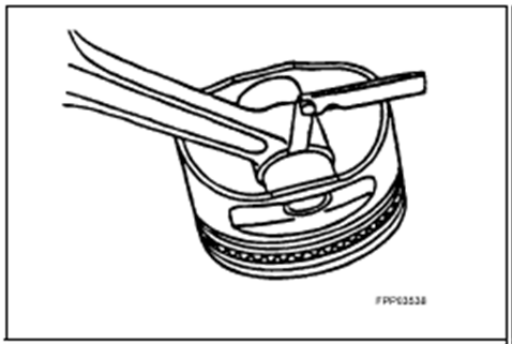
Connecting Rod Twist

- Measure the connecting rod twist on a suitable alignment fixture. Follow the instructions of the fixture manufacturer. Verify the measurement is within specification.



Connecting Rod Piston Pin Side Clearance

- Measure the clearance between the connecting rod and the piston. Verify the measurement is within specification.



Connecting Rod Journal Clearance

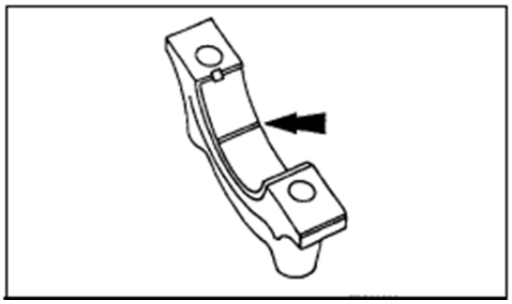
Special Tool(s)

	Plastigage® D81L-6002-B or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

NOTE: The crankshaft connecting rod journals must be within specifications to check the connecting rod bearing journal clearances.

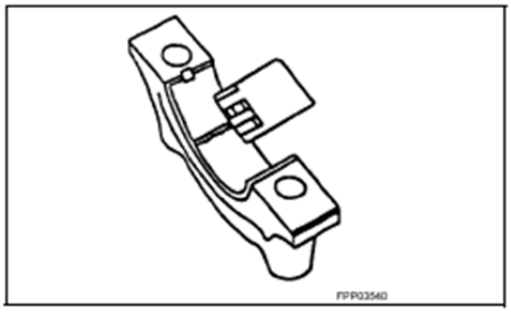
CAUTION: The connecting rod bolts are torque to yield and must be discarded and replaced after this diagnostic test.

1. Remove the connecting rod bearing cap.
2. Position a piece of Plastigage® across the
3. bearing surface.



NOTE: Do not turn the crankshaft during this step.

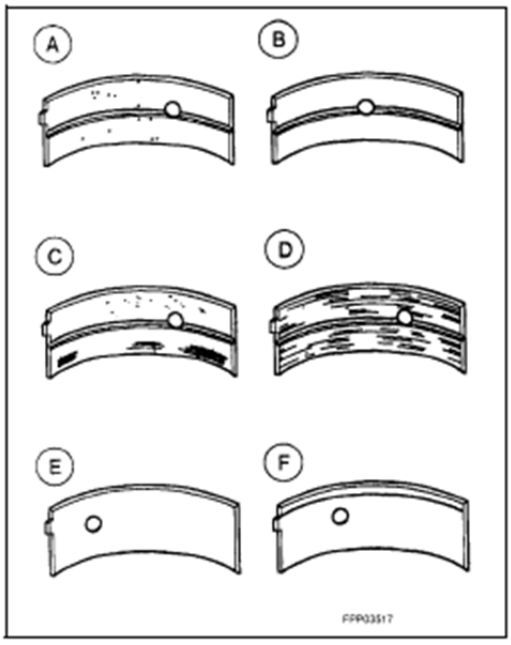
4. Install and torque to specifications, then remove the connecting rod bearing cap.
5. Measure the Plastigage® to get the connecting rod bearing journal clearance. The Plastigage® should be smooth and flat. A change width indicates a tapered or damaged connecting rod bearing or connecting rod.



Bearing Inspection

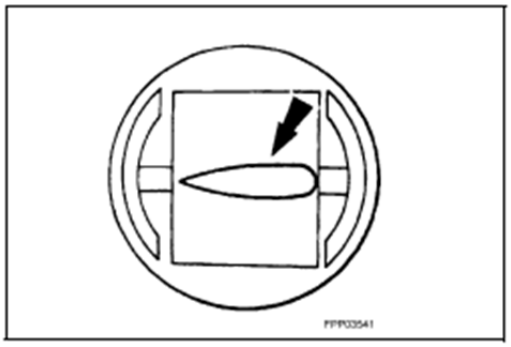
Inspect bearings for the following defects. Possible causes are shown:

- Cratering – fatigue failure (A)
- Spot polishing – improper seating (B)
- Scratching – dirty (C)
- Base exposed – poor lubrication (D)
- Both edges worn – journal damaged (E)
- One edge worn – journal tapered or bearing not seated (F)



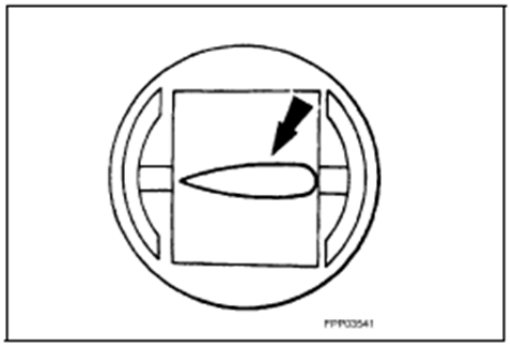
Roller Follower Inspection

- Inspect the roller for flat spots or scoring. If any damage is found, inspect the camshaft lobes and hydraulic lash adjusters for damage.



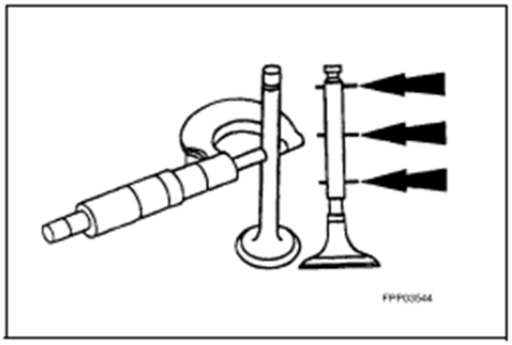
Hydraulic Lash Adjuster Inspection

- Inspect the hydraulic lash adjuster and roller for damage. If any damage is found, inspect the camshaft lobes and valves for damage.



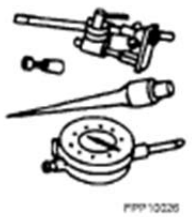
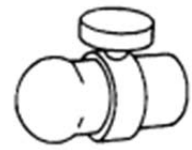
Valve Stem Diameter

- Measure the diameter of each intake and exhaust valve stem at the points shown. Verify the diameter is within specification.



Valve Stem-to-Valve Guide Clearance

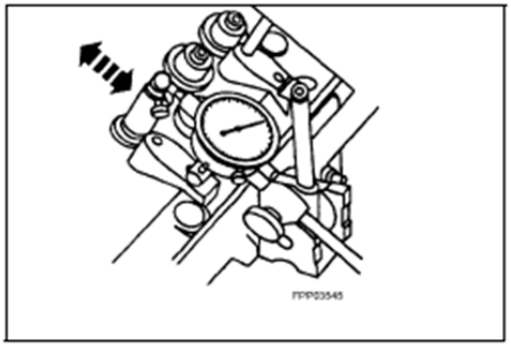
Special Tool(s)

	Dial Indicator with Bracketry TOOL-4201-C or Equivalent
	Valve Stem Clearance Tool TOOL-6505-E or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

NOTE: Valve stem diameter must be within specifications before checking valve stem to valve guide clearance.

NOTE: If necessary, use a magnetic base.

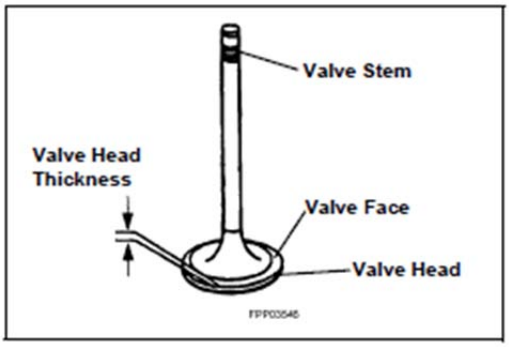
1. Install the Valve Stem Clearance Tool on the valve stem and install the Dial Indicator with Bracketry. Lower the valve until the Valve Stem Clearance Tool contacts the upper surface of the valve guide.
2. Move the Valve Stem Clearance Tool toward the Dial Indicator and zero the Dial Indicator. Move the Valve Stem Clearance Tool away from the Dial Indicator and note the reading. The reading will be double the valve stem-to-valve guide clearance. Valves with oversize stems will need to be installed if out of specification.



Valve Inspection

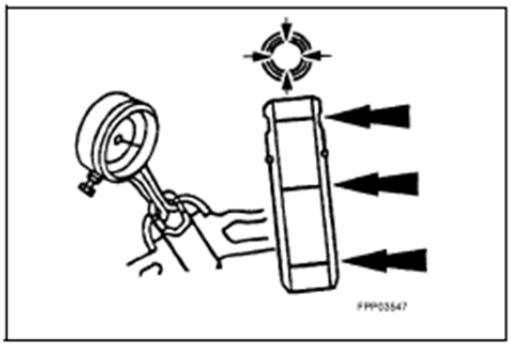
Inspect the following valve areas:

- The end of the stem for grooves or scoring.
- The valve face and the edge for pits, grooves or scores.
- The valve head for signs of burning, erosion, warpage and cracking. Minor pits, grooves and other abrasions may be removed.
- The valve head thickness for wear.



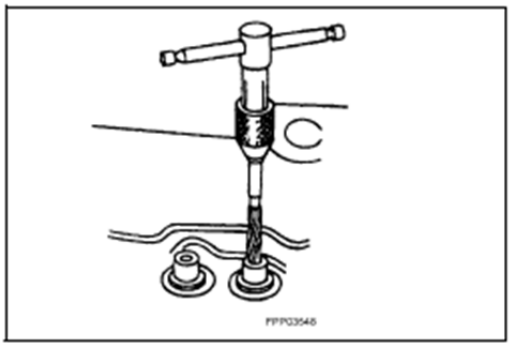
Valve Guide Inner Diameter

1. Measure the inner diameter of the valve guides in two directions where indicated.
2. If the valve guide is not within specifications, ream the valve guide and install a valve with an oversize stem or remove the valve guide and install a new valve guide.



Valve Guide Reaming

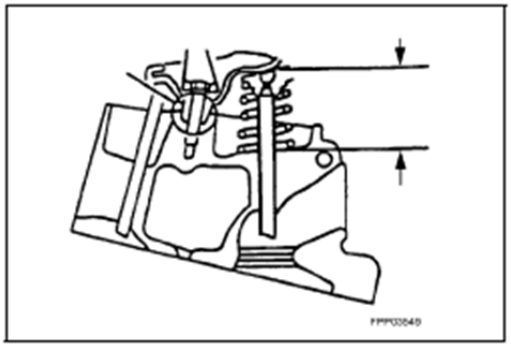
1. Use a hand-reaming kit to ream the valve guide.



2. Reface the valve seat.
3. Clean the sharp edges left by reaming.

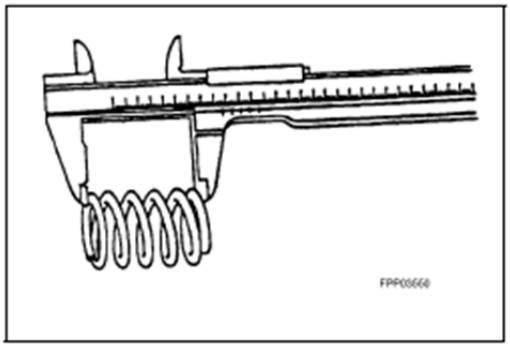
Valve Spring Installed Length

- Measure the installed length of each valve spring.



Valve Spring Free Length

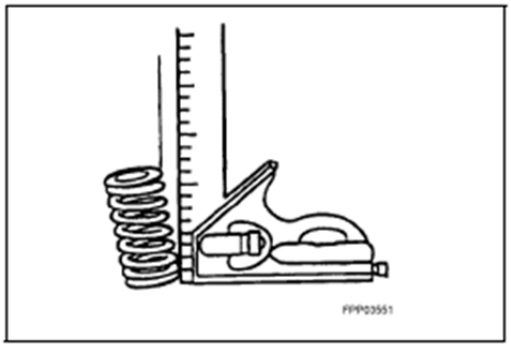
- Measure the free length of each valve spring.



Valve Spring Out-of-Square

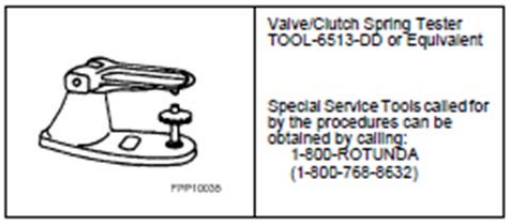
Measure the out-of-square on each valve spring.

- Turn the valve spring and observe the space between the top of the valve spring and the square. Replace the valve spring if it is out of specification.

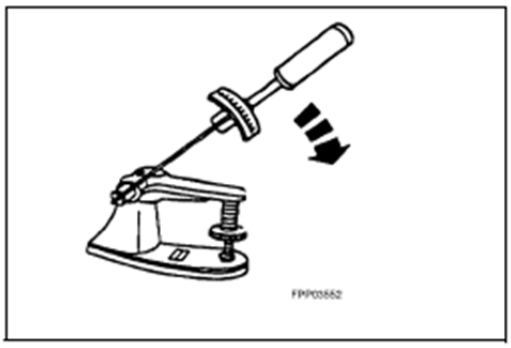


Valve Spring Compression Pressure

Special Tool(s)



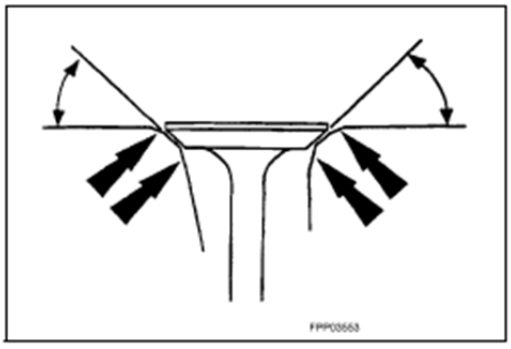
- Use the Valve/Clutch Spring Tester to check the valve springs for proper strength at the specified valve spring length.



Valve and Seat Refacing Measurements

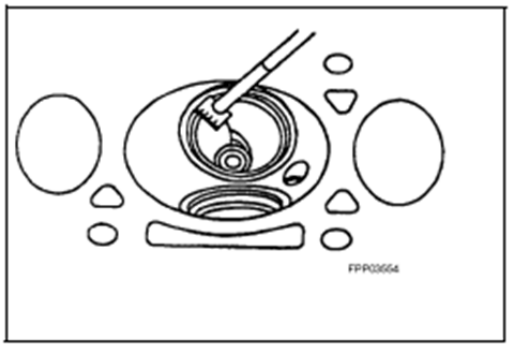
NOTE: After grinding valves or valve seats, check valve clearance.

- Check the valve seat and valve angles.



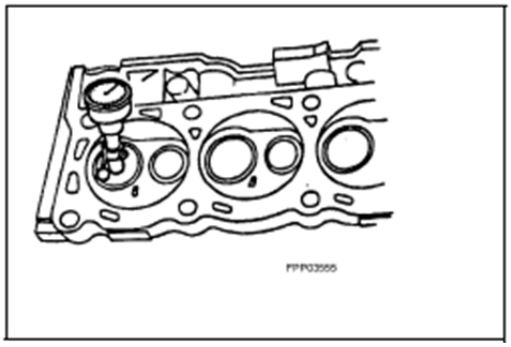
Valve Seat Width

- Measure the valve seat width. If necessary, grind the valve seat to specification.



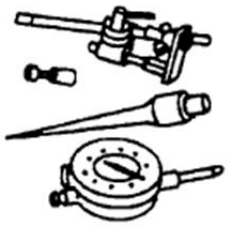
Valve Seat Runout

- Use the Valve Seat Runout Gauge to check valve seat runout.

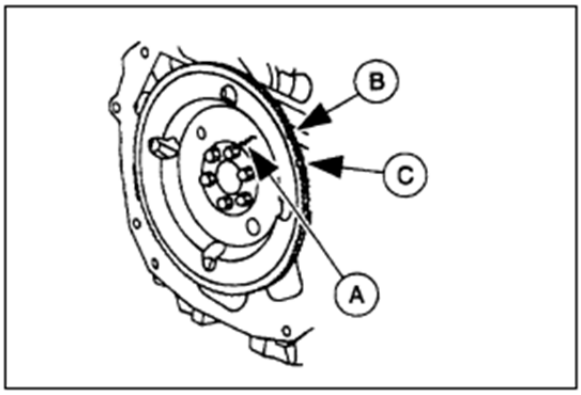


Flywheel Inspection

Special Tool(s)

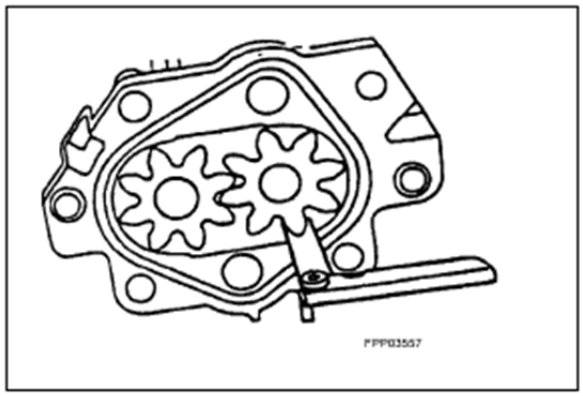
 FPP10026	Dial Indicator with Bracketry TOOL-4201-C or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

1. Inspect the flywheel for:
   - Cracks (A).
   - Worn ring gear teeth (B).
   - Chipped or cracked ring gear teeth (C).
2. Inspect the flywheel ring gear runout.



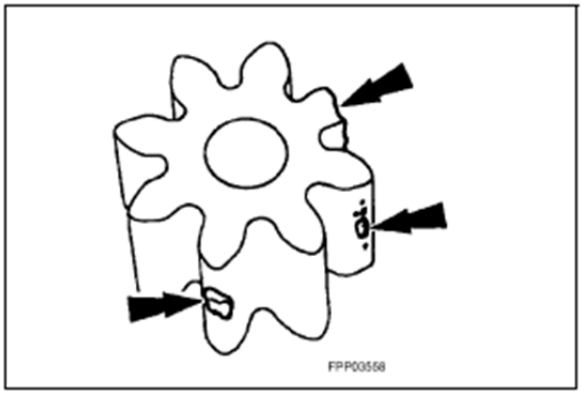
Oil Pump Gear Radial Clearance

- Measure the clearance between the rotor and the pump housing.
-



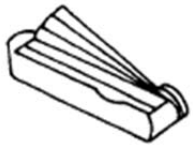
Oil Pump Rotor Inspection

- Inspect the oil pump rotor tips for damage or wear.

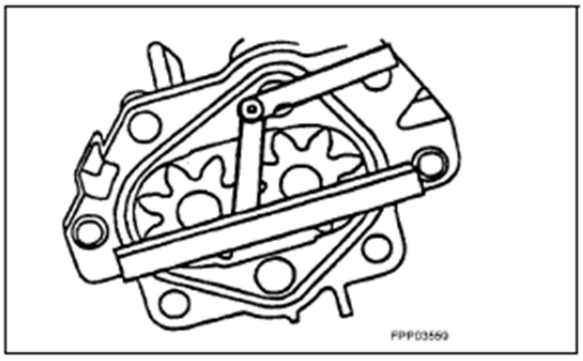


Oil Pump Side Clearance

Special Tool(s)

 FPP10033	Feeler Gauge D81L-4201-A or Equivalent
FPP10036	Straight Edge D83L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

- Place the Straight Edge across the top of the oil pump and rotors and use the Feeler Gauge to measure the clearance between the rotors and the Straight Edge.



Cylinder Bore Honing

Special Tool(s)

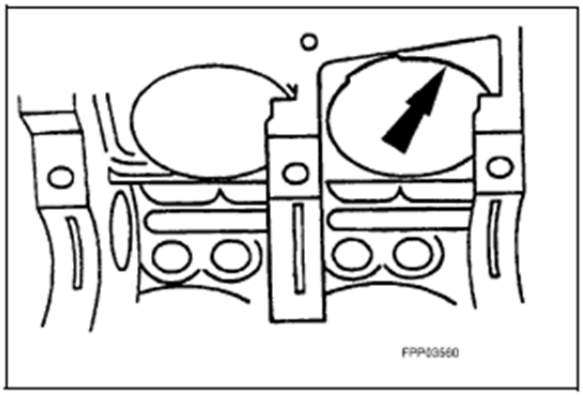
FPP10037	Engine Cylinder Hone Set T73L-6011-A Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

NOTE: Before any cylinder bore is honed, all main bearing caps must be installed so the crankshaft bearing bores will not become distorted.

NOTE: To correct taper or out-of-round, bore the cylinder block.

NOTE: Honing should be done when fitting new piston rings or to remove minor surface.

- Hone with the Engine Cylinder Hone Set, at a speed of 300-500 rpm and a hone grit of 180-220 to provide the desired cylinder bore surface finish.



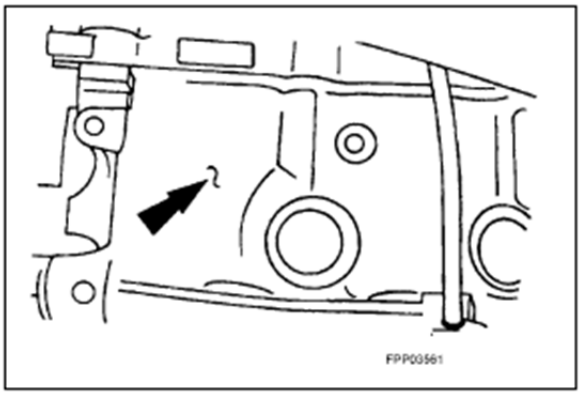
Cylinder Bore Cleaning

CAUTION: If these procedures are not followed, rusting of the cylinder bores may occur.

1. Clean the cylinder bores with soap or detergent and water.
2. Thoroughly rinse with clean water and wipe dry with a clean, lint-free cloth.
3. Use a clean, lint-free cloth and lubricate the cylinder bores.
    - Use Engine Oil XO-10W30-QSP or -DSP or equivalent meeting Ford specification ESEM2C153-E.

Cylinder Block Repair - Cast Iron Porosity Defects

CAUTION: Do not attempt to repair cracks, areas where temperature will exceed 260°C (500°F) or areas exposed to engine coolant or oil. These areas will not repair and could cause future failure.



Repair porosity defects with an epoxy sealer meeting Ford specification M3D35-A (E).

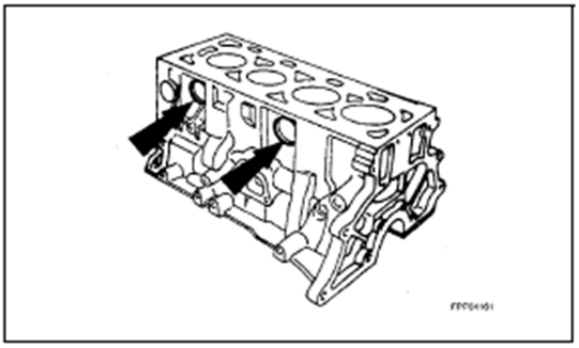
1. Clean the surface to be repaired to a bright, oil-free metal surface.
2. Chamfer or undercut the repair area to a greater depth than the rest of the cleaned surface. Solid metal must surround the area to be repaired.
3. Apply the epoxy sealer and heat-cure with a 250- watt lamp placed 254 mm (10 inches) from the repaired surface, or air dry for 10-12 hours at a temperature above 10°C (50°F).
4. Sand or grind the repaired area to blend with the general contour of the surface.
5. Paint the surface to match the rest of the cylinder block.

Cylinder Block Core Plug Replacement

Special Tool(s)

FPP10000	Impact Slide Hammer T50T-100-A Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

1. Use a slide hammer or tools suitable to remove the cylinder block core plug.



2. Inspect the cylinder block plug bore for any damage that would interfered with the proper sealing of the plug. If the cylinder block plug bore is damaged, bore for the next oversize plug.

NOTE: Oversize plugs are identified by the OS stamped in the flat located on the cup side of the plug.

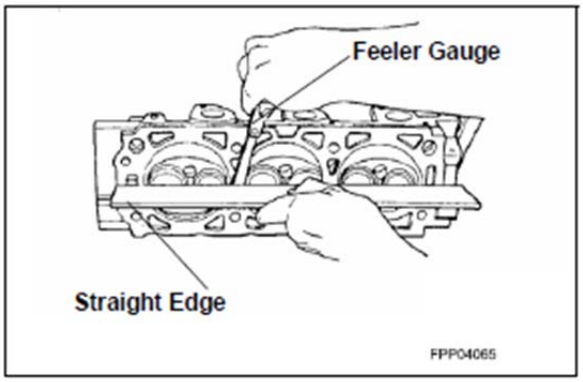
3. Coat the cylinder block core plug and bore lightly with Threadlock® 262 E2FZ-19554-B or equivalent meeting Ford specification WSK-M2G351-A6 and install the cylinder block core plug.

Cylinder Head – Distortion

Special Tool(s)

FPP10036	Straightedge 303-D039 (D83L-4201-A) or equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

- Use a straight edge and a feeler gauge to inspect the cylinder head for flatness. Compare with specifications. If the cylinder head is distorted, install a new cylinder head.

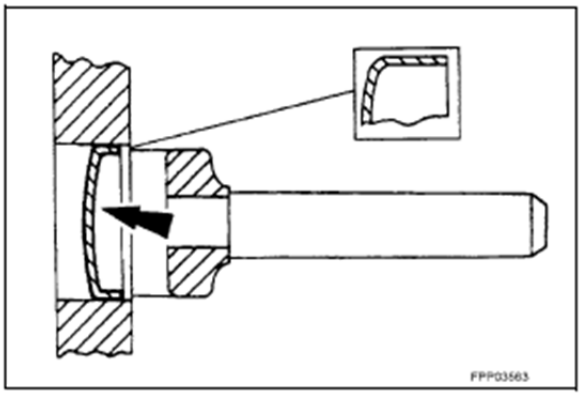


Cylinder Block Core Plug – Cup-Type

CAUTION: Do not contact the flange when installing a cup type cylinder block core plug as this could damage the sealing edge and result in leakage.

NOTE: When installed, the flanged edge must be below the chamfered edge of the bore to effectively seal the bore.

- Use a fabricated tool to seat the cup type cylinder block core plug.

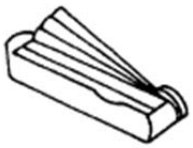


Cylinder Block Core Plug – Expansion-Type
CAUTION: Do not contact the crown when installing an expansion type cylinder block core plug. This could expand the plug before seating and result in leakage.

- Use a fabricated tool to seat the expansion type cylinder block core plug.

Spark Plug Thread Repair

Special Tool(s)

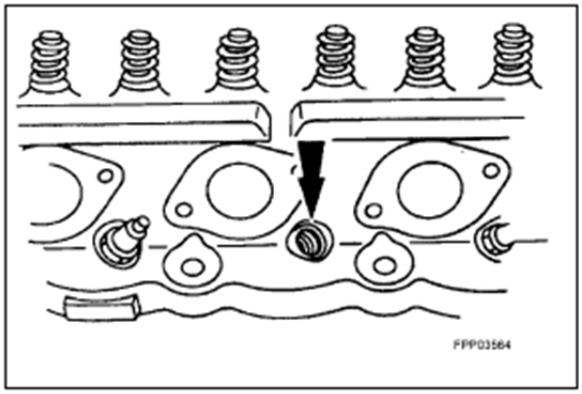
FPP10038	Tapersert Installation Kit 107-R0921 or Equivalent
 FPP10033	Feeler Gauge D81L-4201-A or Equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

CAUTION: The cylinder head must be removed from the engine before installing a tapersert. If this procedure is done with the cylinder head on the engine, the cylinder walls can be damaged by metal chips produced by the thread cutting process.

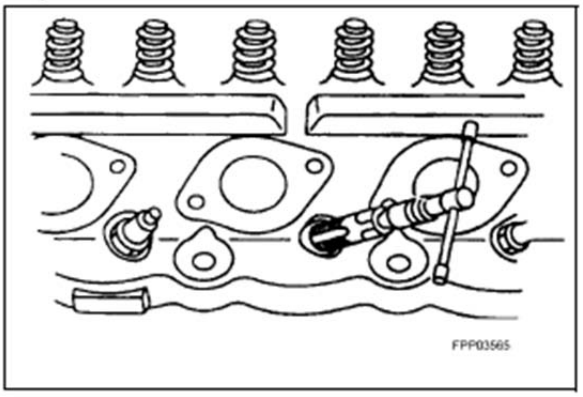
CAUTION: Do not use power or air-driven tools for finishing taperserts.

NOTE: This repair is permanent and will have no effect on cylinder head or spark plug life.

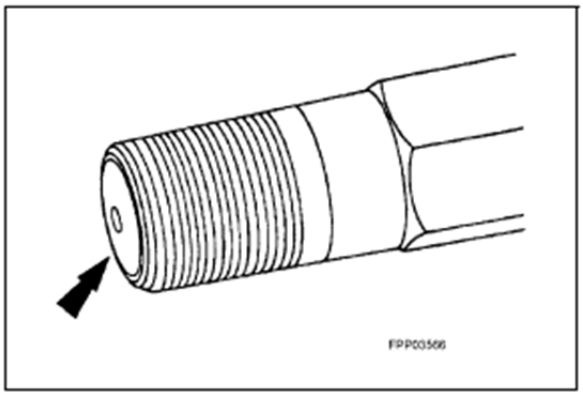
1. Clean the spark plug seat and threads.



2. Start the tap into the spark plug hole, being careful to keep it properly aligned. As the tap begins to cut new threads, apply aluminum cutting oil

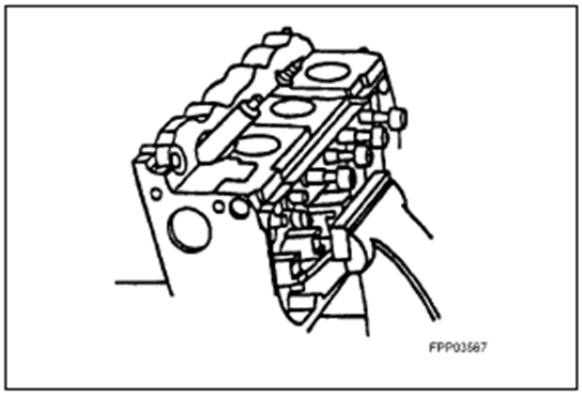


3. Continue cutting the threads and applying oil until the stop ring bottoms against the spark plug seat.
4. Remove the tap and metal chips.
5. Coat the threads of the mandrel with cutting oil. Thread the tapersert onto the mandrel until one thread of the mandrel extends beyond the tapersert.

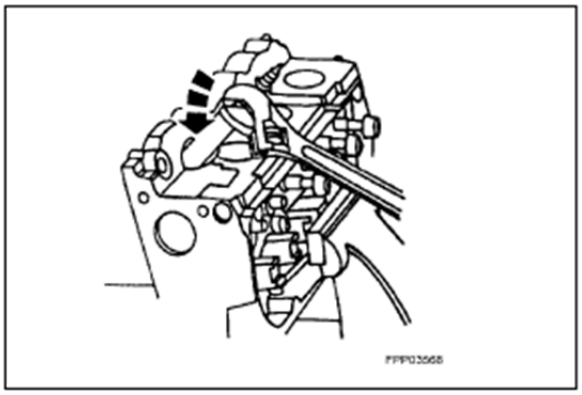


NOTE: A properly installed tapersert will be either flush with or 1.0 mm (0.039 inch) below the spark plug gasket seat.

6. Tighten the tapersert into the spark plug hole.



7. Turn the mandrel body approximately one-half turn counterclockwise and remove.



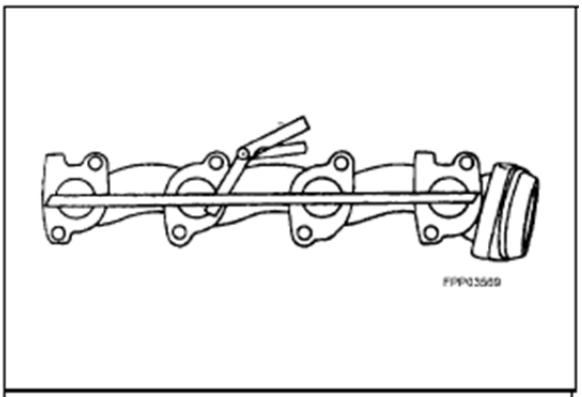
Exhaust Manifold Straightness

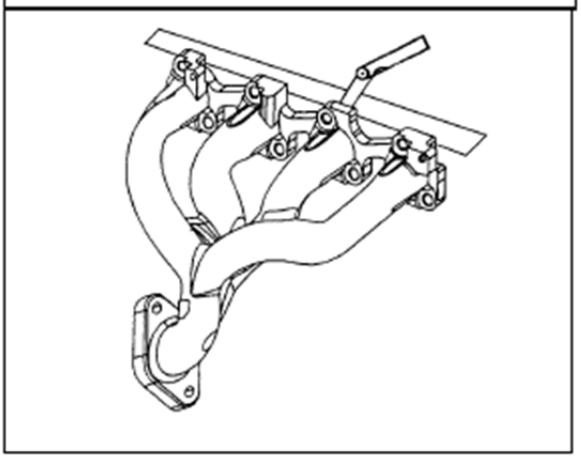
Special Tool(s)

FPP10036	Straightedge 303-D039 (D83L-4201-A) or equivalent Special Service Tools called for by the procedures can be obtained by calling: 1-800-ROTUNDA (1-800-768-8632)

- Place the Straightedge across the exhaust manifold flanges and check for warping with a feeler gauge.

NOTE: The exhaust manifold shown is a typical exhaust manifold.





SPECIFICATIONS

GENERAL SPECIFICATIONS	
Epoxy Sealer	M3D35-A (E)
Threadlock 262 E2FZ-19554-B	WSK-M2G351-A6
Super Premium SAE5W20	WSS M2C930-A

NOTE: Ford engines are designed to perform with engine oils that are licensed by the American Petroleum Institute (API), and oils carrying the most current API Classification SJ or greater must be used.

TSG-416 ENGINE

INDEX

Subject

General Information **Page**

Special Tools..... 02 – 3
Positive Crankcase Ventilation System..... 02 – 5
Component Location..... 02 – 6

Engine Repair

Valve Cover – Removal ..... 02 – 10
Valve Cover – Installation..... 02 – 10
Camshaft – Removal ..... 02 – 11
Camshaft – Installation..... 02 – 12
Valve Stem Seal – Removal..... 02 –13
Valve Stem Seal – Installation..... 02 – 14
Intake Manifold – Removal..... 02 – 15
Intake Manifold – Installation..... 02 – 15
Exhaust Manifold – Removal..... 02 – 16
Exhaust Manifold – Installation..... 02 – 16
Cylinder Head – Removal..... 02 – 17
Cylinder Head – Installation..... 02 - 19
Oil Pump - Removal..... 02 – 21
Oil Pump – Installation..... 02 – 22
Crankshaft Rear Oil Seal – Removal..... 02 – 23
Crankshaft Rear Oil Seal – Installation..... 02 – 23
Camshaft Follower / Hydraulic Lash Adjuster – Removal..... 02 – 24
Camshaft Follower / Hydraulic Lash Adjuster – Installation..... 02 – 24
Oil Pan – Removal..... 02 – 25
Oil Pan – Installation..... 02 – 25
Pickup tube / deflector – Removal..... 02 – 26
Pickup tube / deflector – Installation..... 02 – 26
Crankshaft main bearings - Removal..... 02 – 27
Crankshaft main bearings – Installation..... 02 – 27
Connecting Rod Bearings - Removal..... 02 – 28
Connecting Rod Bearings – Installation..... 02 – 28
Piston – Removal..... 02 – 29
Piston – Installation..... 02 – 30
Flywheel – Removal..... 02 – 31
Flywheel – Installation..... 02 – 31
Timing Chain and Sprockets – Removal..... 02 – 32
Timing Chain and Sprockets – Installation..... 02 – 33
Oil Level Indicator – Removal ..... 02 – 35
Oil Level Indicator – Installation..... 02 – 35
Oil Level Filter and Adapter – Removal..... 02 – 36
Oil Level Filter and Adapter – Installation..... 02 – 36

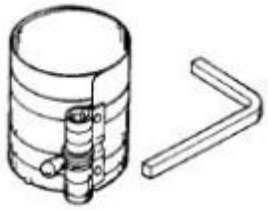
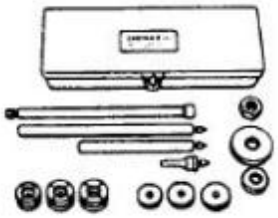
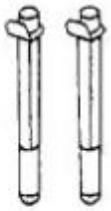
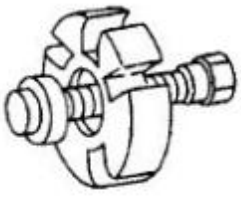
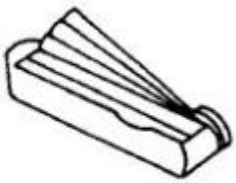
INDEX (CONT.)

Subject	Page
Disassembly	**02 - 37**
Subassemblies	
Cylinder Block	02 – 44
Piston – Disassembly	02 – 45
Piston – Assembly	02 – 45
Cylinder Head Disassembly	02 – 46
Cylinder Head Assembly	02 – 47
Assembly	**02 – 48**
SPECIFICATIONS	**02 – 58**

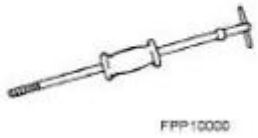
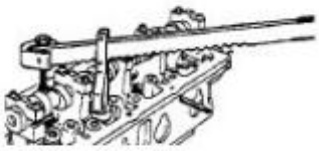
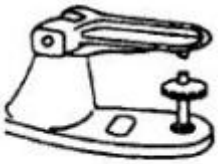
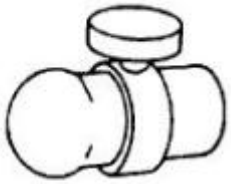
Note: For engine diagnosis, refer to Section 01

GENERAL INFORMATION

Special Tools

	Valve Spring Compressor T81P-6513-A or Equivalent		Seal Remover T92C-6700-CH or Equivalent
	Piston Ring Compressor D81L-6002-C or Equivalent		Dial Indicator with Bracketry TOOL-4201-C or Equivalent
	Camshaft Bearing Set T65L-6250-A or Equivalent		Cylinder Ridge Reamer T64L-6011-EA or Equivalent
	Connecting Rod Guide Tool T93P-6136-A or Equivalent		Vibration Damper Remover Adapter T82L-6316-B or Equivalent
	Crankshaft Damper Remover T58P-6316-D or Equivalent		Feeler Gauge D81L-4201-A or Equivalent

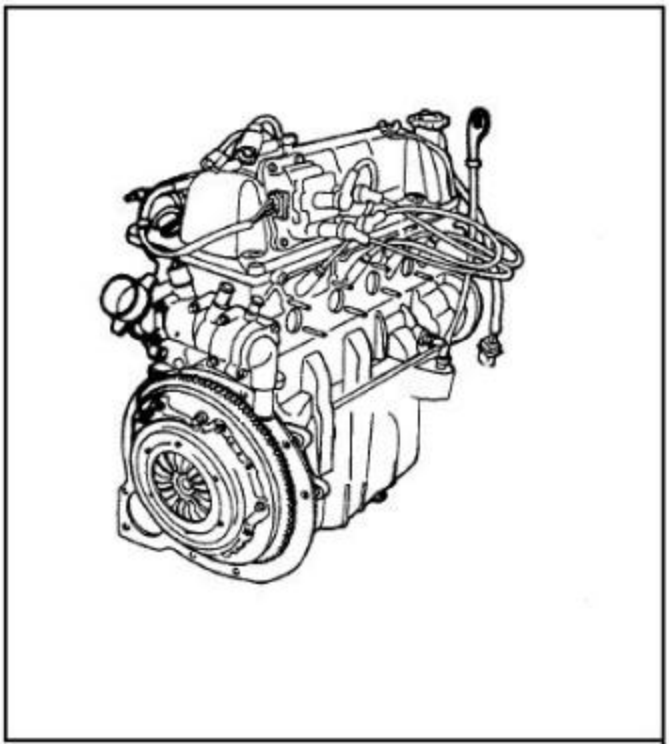
Special Tools

 FPP10000	Impact Slide Hammer T50T-100-A or Equivalent		Valve Seal Tool 21-024 or Equivalent
	Pound/Inch Torque Wrench Purchase from Local Tool Dealer		Extra space
 FPP10035	Spring Tester 303-006 or TOOL-6513-DD or Equivalent		Extra space
 FPP10034	Valve Clearance Measuring Tool 100-002 or TOOL-6505-E or Equivalent		Extra space
	Spring Testing Fixture 21-024 or Equivalent		Extra space

Description

The 1.6L 4 cylinder Zetec Rocam engine has been developed with the highest technology. Its main characteristics are:

- electronic controlled multipoint sequential injection
- roller finger follower camshaft
- intake manifold made of aluminum
- high resistance aluminum cylinder hea
- steel oil pan.



Fuel System

The electronic fuel injection (EFI) system is electronically controlled by an ECM module which carefully controls fuel-air mixture along with spark timing, depending on information received from various sensors.

Intake Manifold

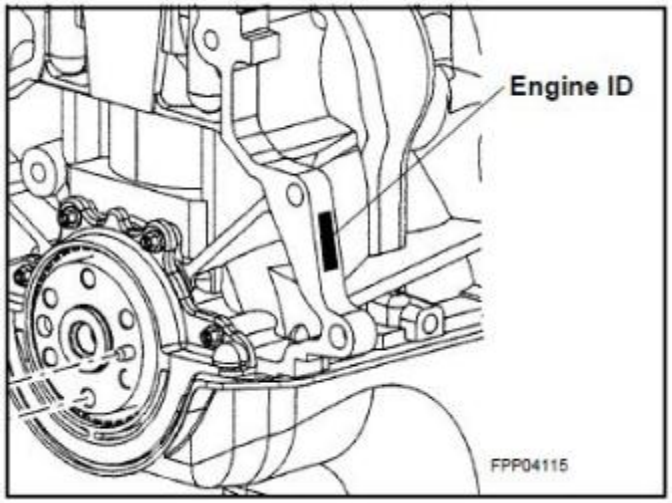
The intake manifold is made of aluminum. It consists of two pieces.

Cylinder Head

The Zetec Rocam engine cylinder head is entirely made of aluminum which improves the thermal characteristics and reduces weight. The assembly is attached using a multi-layer steel gasket and 12 bolts.

Oil Pan

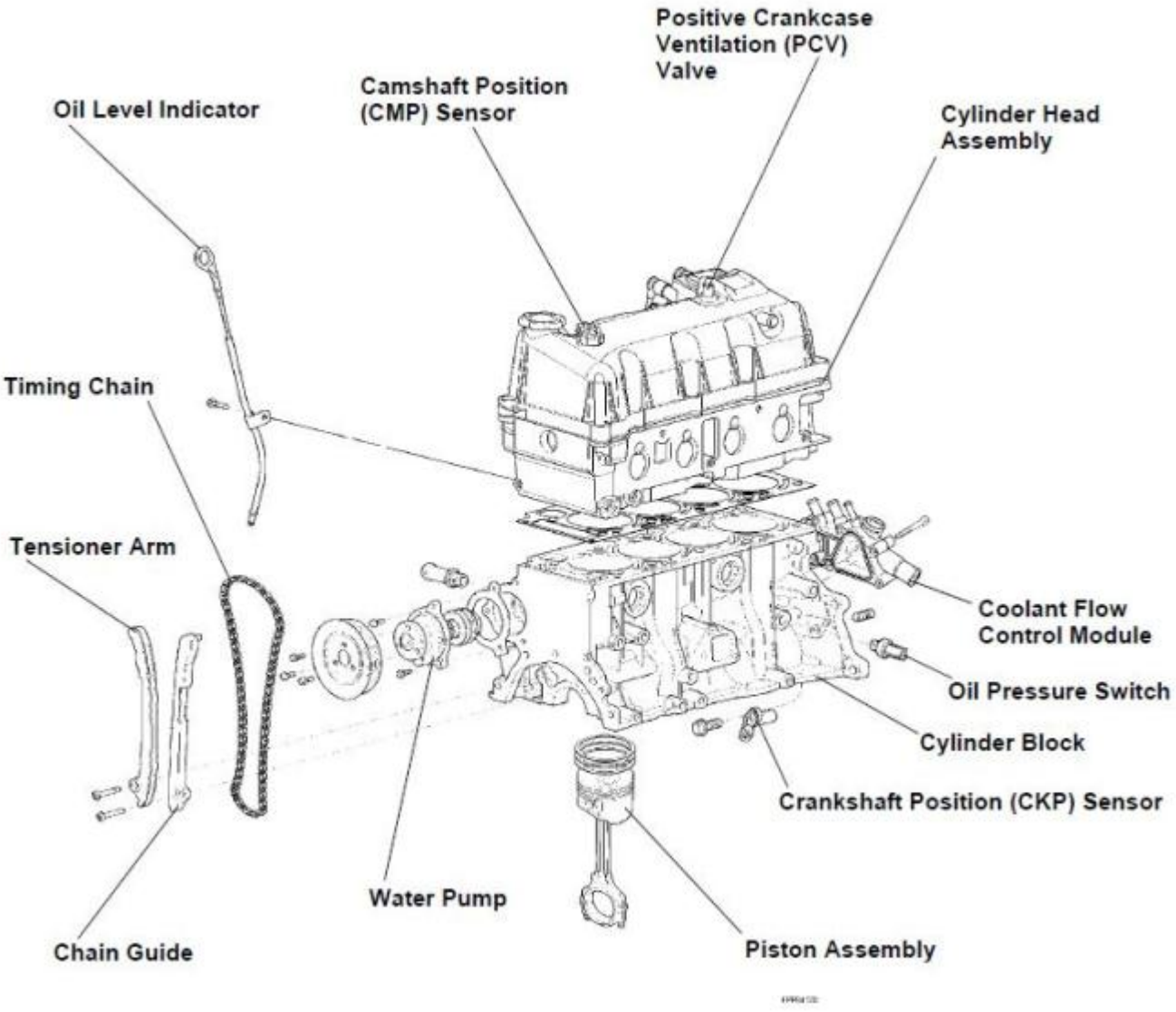
The Zetec Rocam engine oil pan is made of steel. The gasket must always be replaced whenever the oil pan is removed.



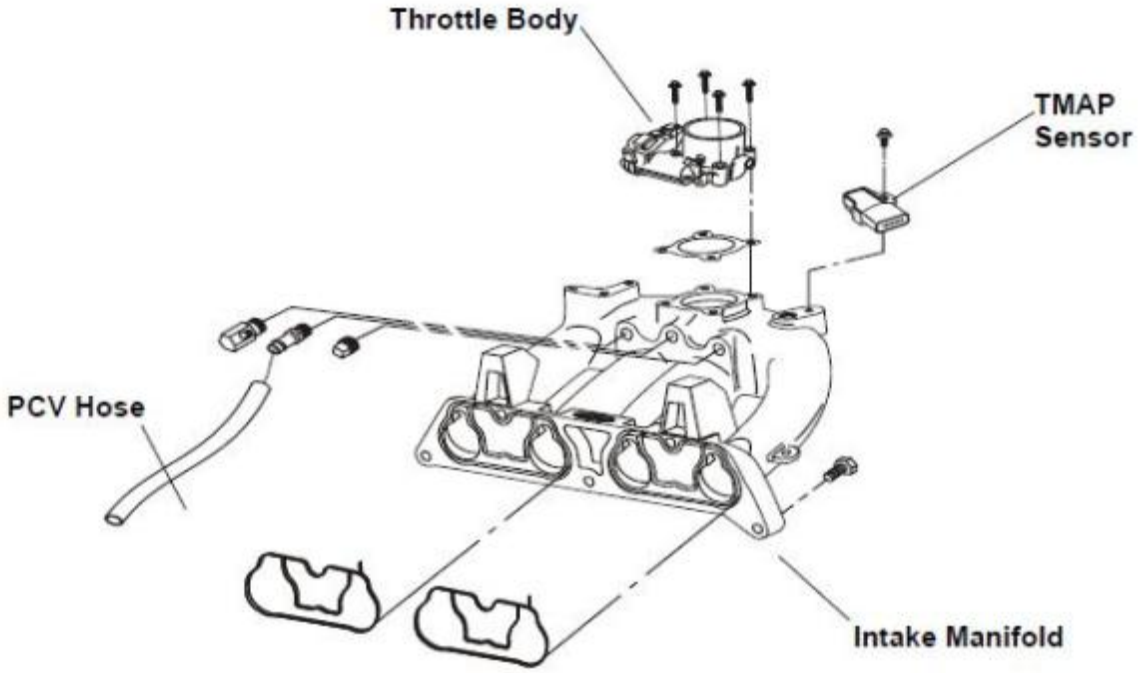
Engine Identification Number

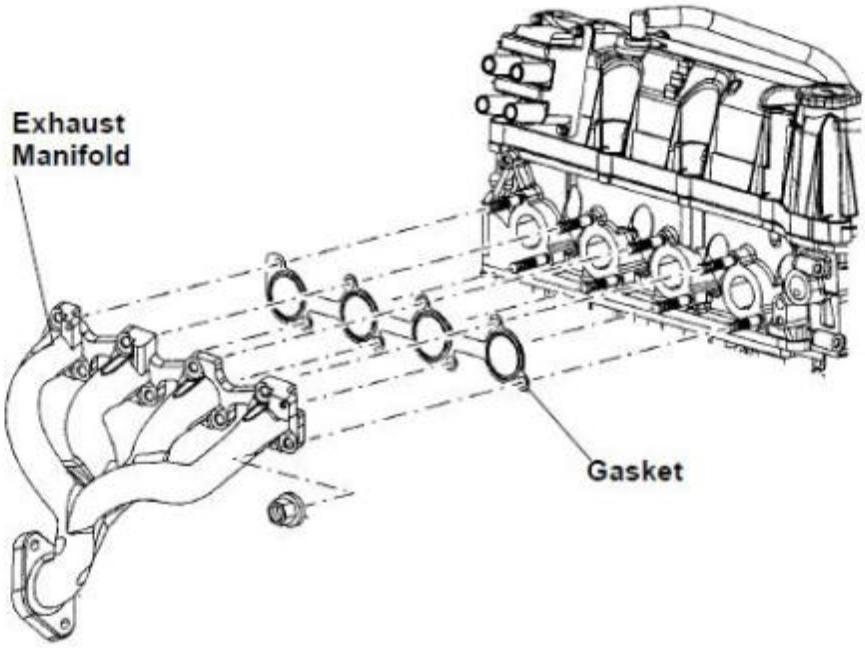
The engine identification number is marked on the right side of the cylinder block as shown.

Component Location

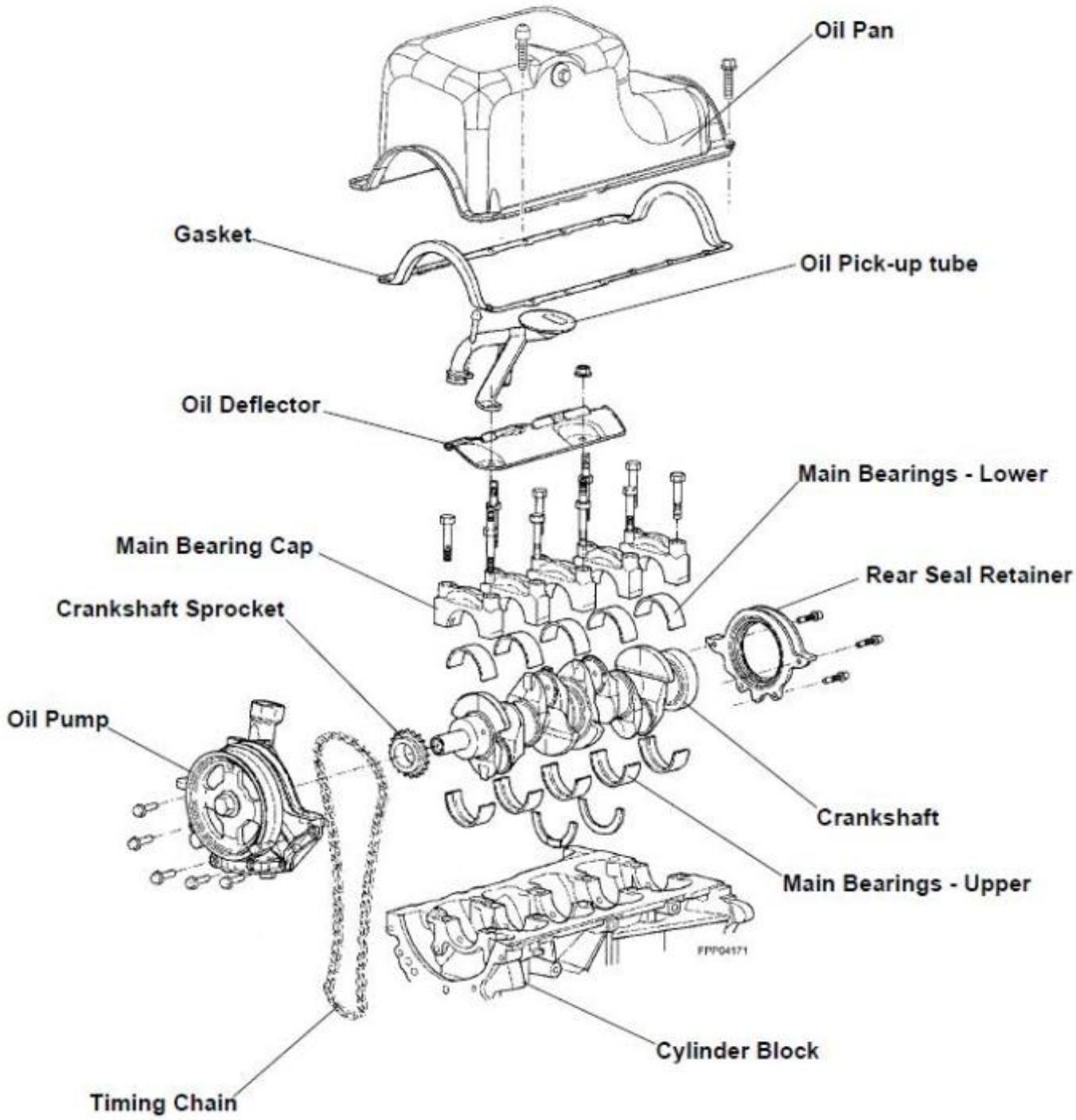


Component Location

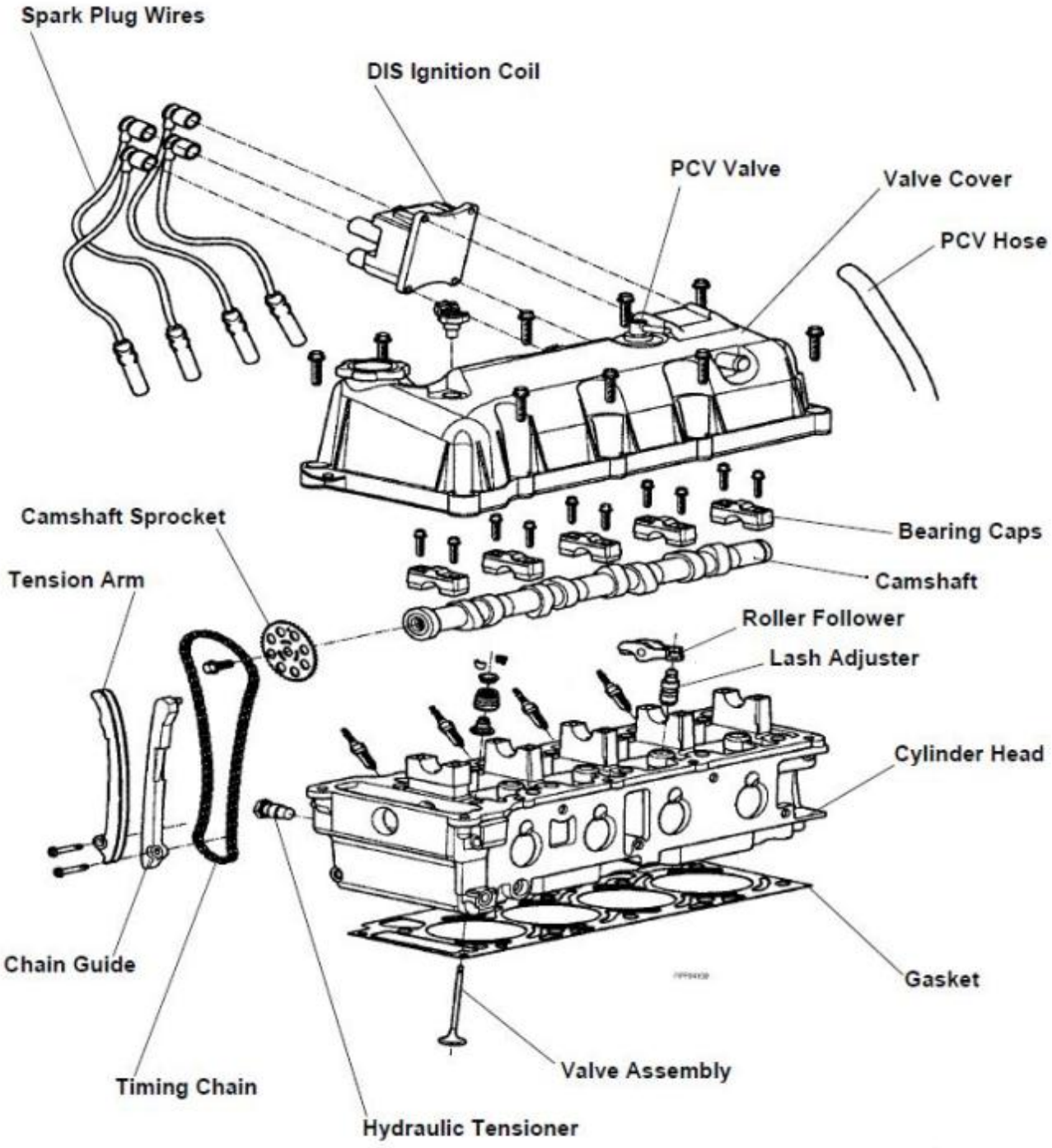




Component Location



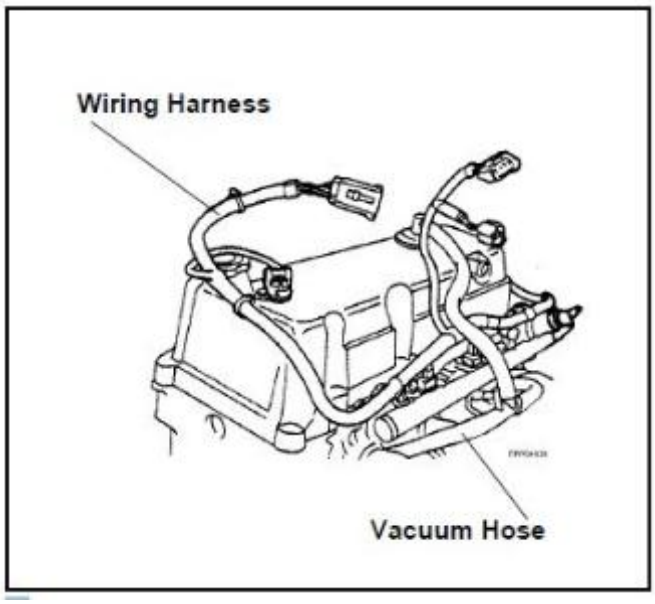
Component Location



ENGINE REPAIR

Valve Cover - Removal

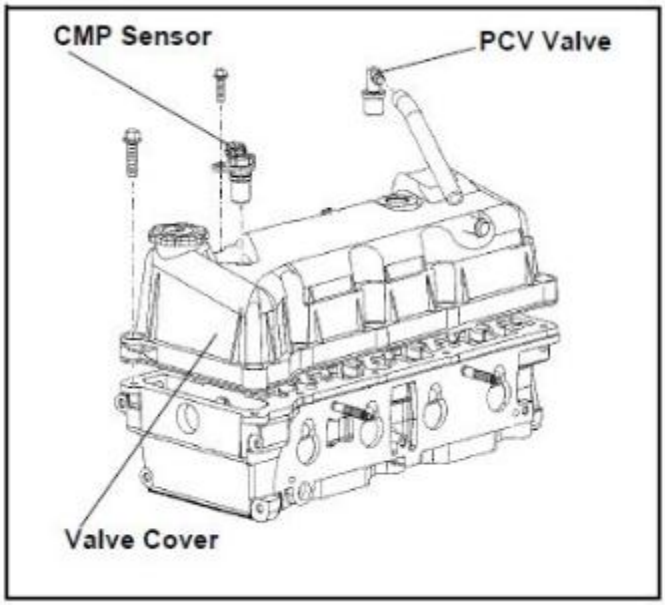
1. Remove any necessary wiring and vacuum hoses. Mark connections and routing as necessary to assure they are returned as they were removed.



2. Remove DIS coil and set aside - refer to Section 03.
3. Remove bolts.
4. Remove valve cover and gasket.

Valve Cover - Installation

1. Contact surfaces must be clean and free of oil.
2. Install a new gasket and valve cover.

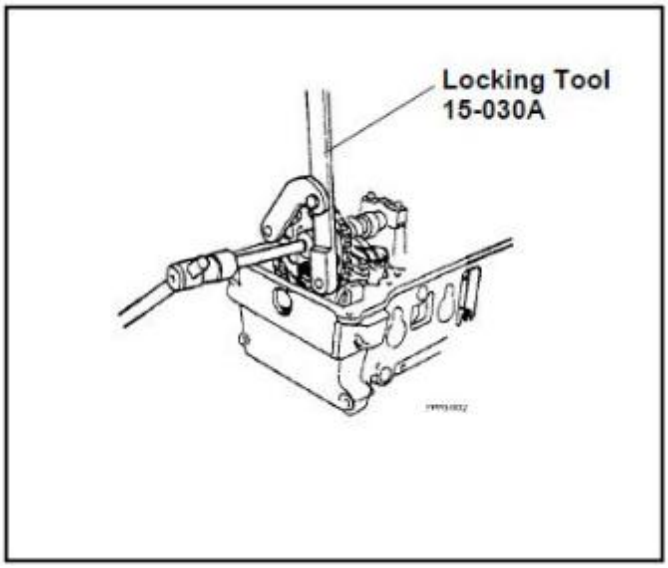


3. Install bolts. Tighten to 7 lb.ft. (9 Nm).
4. Install DIS coil - refer to Section 03.
5. Reconnect any wiring and vacuum hoses removed.
    a. CAM Sensor, PCV, etc.

Camshaft- Removal

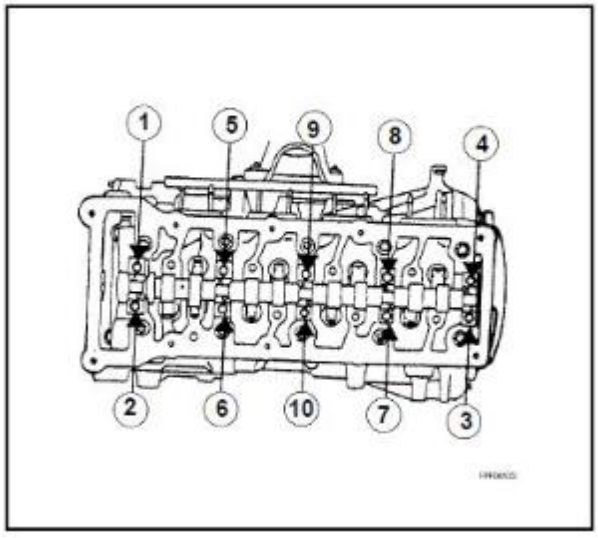
NOTE: Store components to ensure assembly in the same order as they were removed.

1. Remove valve cover -- Refer to “Valve Cover - Removal” on page 10.
2. Using tool 15-030A to lock camshaft sprocket, remove bolt.

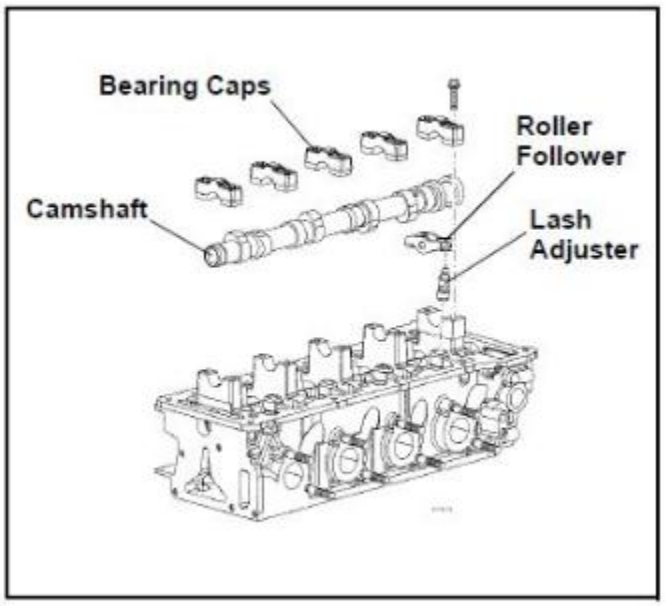


CAUTION: During camshaft removal, the camshaft sprocket and chain must remain engaged and the chain tensioned in order to keep timing links aligned. If chain is allowed to slacken or disengage with sprocket, the oil pump will have to be removed, and the timing chain realigned - refer to timing chain assembly xxx.

3. Separate camshaft sprocket and chain from camshaft while maintaining tension on the chain.
4. Remove bolts and camshaft bearing caps evenly in the sequence shown.



5. Remove camshaft, lower bearings, roller followers and lash adjusters.

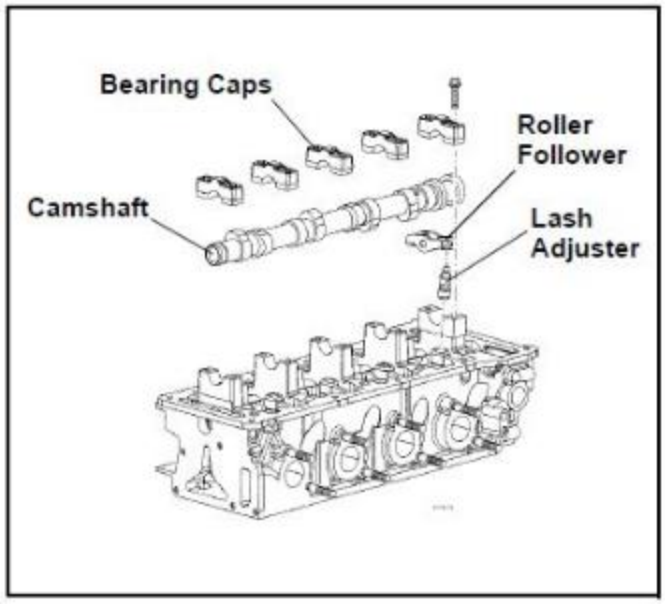


Refer to Section 01 for camshaft and bearing service.

Camshaft - Installation

NOTE: All components must be clean and assembled in the same positions as removed. Lubricate contact surfaces with clean engine oil.

1. Install lash adjusters.
2. Install roller followers.

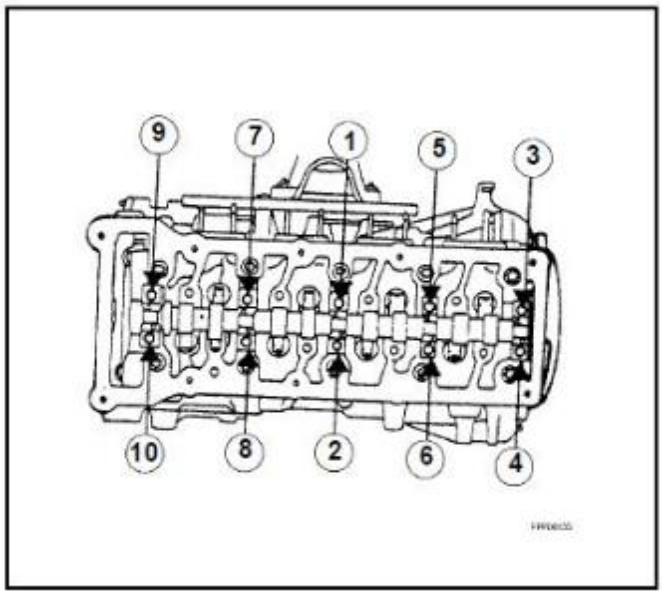


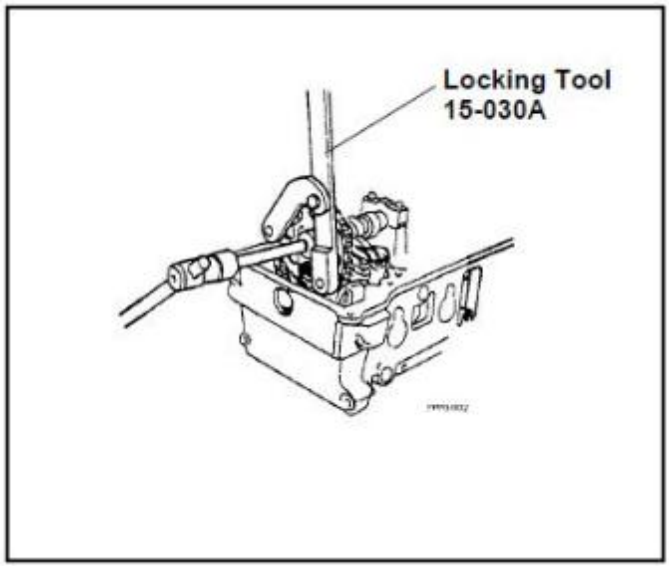
NOTE: The chamfer on the camshaft bearing caps must be facing the chain housing. Rotate camshaft so keyway will align with sprocket.

3. Carefully install camshaft, bearings, caps and bolts finger tight.
4. Tighten bolts in the sequence shown in 3 steps to 6- 7 lb.ft. (8-10 Nm).
5. Install camshaft sprocket with chain onto camshaft while maintaining tension on the chain.

CAUTION: The camshaft sprocket and chain must remain engaged and the chain tensioned in order to keep timing links aligned. If chain is allowed to slacken or disengage with sprocket, the oil pump will have to be removed, and the timing chain realigned.

6. Using tool 15-030A, install bolt and tighten to 52-59 lb.ft. (70-80 Nm).





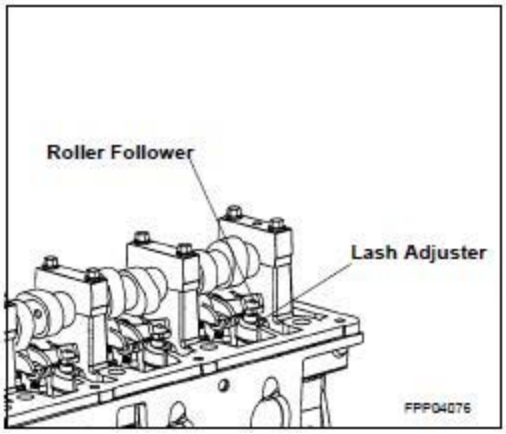
7. Install valve cover -- Refer to “Valve Cover - Installation” on page 10

Valve Stem Seal - Removal

NOTE: If the valve or valve seat has not been damaged, the valve spring, seal, retainer or keys may be replaced by holding the affected valve closed using compressed air.

Use an appropriate air line tool installed in the spark plug hole. A minimum of 965 kPa (140 psi) line pressure is required. If air pressure does not hold the valve shut, the valve is damaged or burned and the cylinder head must be removed and serviced.

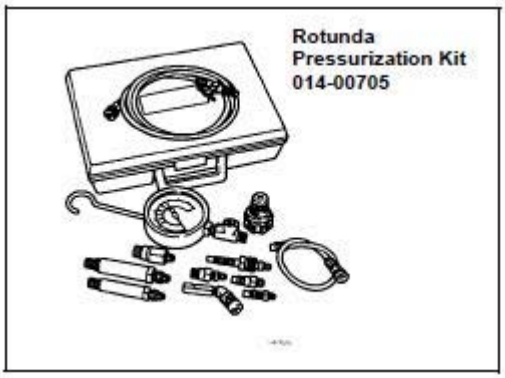
1. Remove valve cover -- Refer to “Valve Cover - Removal” on page 10.
2. Rotate the camshaft so the roller follower for the valve to be serviced is on the heel of the cam.
3. Using a suitable valve spring compressor tool, compress and hold down the valve spring. Slide out the roller follower over the lash adjuster.



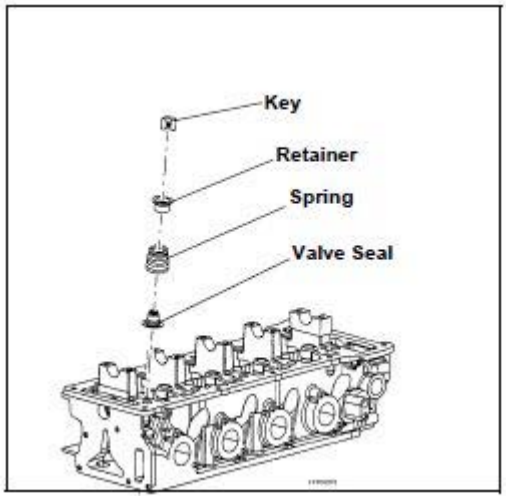
4. Replace spark plug for cylinder being serviced with an air line adapter. Mark location so spark plug is returned to the same cylinder.

CAUTION: The crankshaft may rotate when air pressure is applied. Remove all objects from fan area such as lights, extension cords, etc.

5. Turn on air supply and pressurize cylinder. Air pressure may rotate the crankshaft until the piston reaches the bottom of the stroke.



6. Using a suitable valve spring compressor, compress the valve spring and remove the keys and retainer. Remove and discard the stem seal.



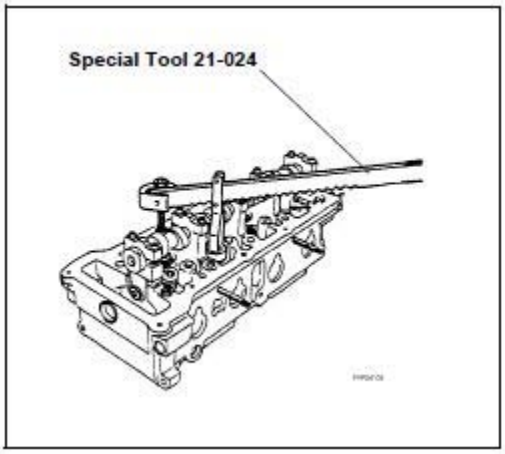
7. If air pressure has forced the piston to the bottom of the cylinder, any removal of air pressure will allow the valve(s) to drop into the cylinder. Wrap a rubber band, tape or string around the end of the valve stem in such a way to prevent the valve from falling in and to allow enough travel to check the valve for binds
8. Inspect the valve stem for damage. Rotate the valve and check the stem tip for eccentric movement. Move the valve up and down through normal travel in the valve guide and check the stem for any binding. If the valve has been damaged, it will be necessary to remove the cylinder head as outlined in this section.

Valve Stem Seal - Installation

NOTE: All components must be clean and assembled in the same positions as removed. Lubricate contact surfaces with clean engine oil.

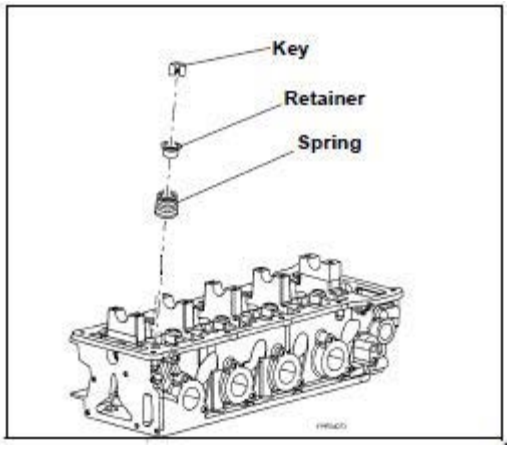
CAUTION: Valve stem seal can be cut by grooves in valve stem. A damaged seal will leak causing oil burning and valve fouling.

1. Carefully slide oil seal over valve stem.
2. Install new valve seal using special tool 21-024 (optional T95P-6565A)

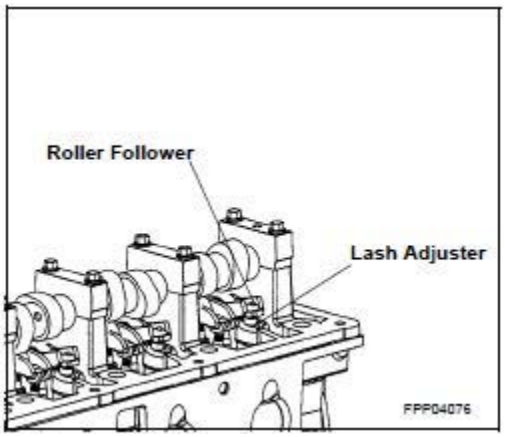


NOTE: Apply a small amount of Ford Multi-purpose Grease D0A2-19584-AA, or equivalent, meeting Ford specification ESR-M1C159-A to valve spring retainer key to hold in place during installation.

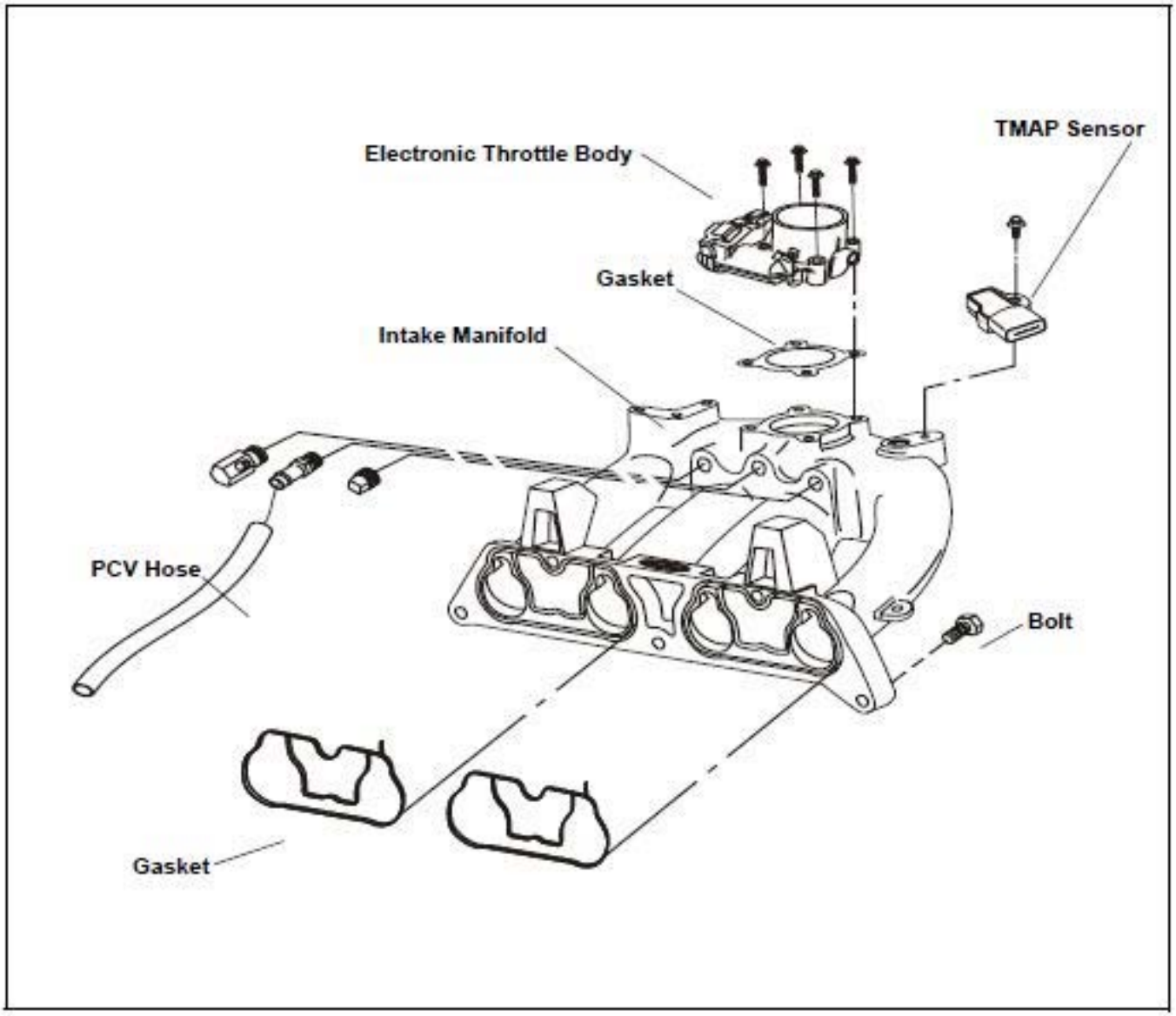
3. With cylinder pressurized and using a suitable spring compressor tool, install valve spring, retainer and locks.



4. Release air pressure and remove air adapter. Install spark plug in proper cylinder.
5. Grease contact surfaces of roller follower with Ford Multi-purpose Grease D0AZ-19584-AA, or equivalent, meeting Ford specification ESRM1C159-A.
6. Using spring compressor, compress and hold down the valve and spring. Slide the roller finger follower into place over valve and lash adjuster. Release spring.



7. Install valve cover -- Refer to “Valve Cover - Installation” on page 10.



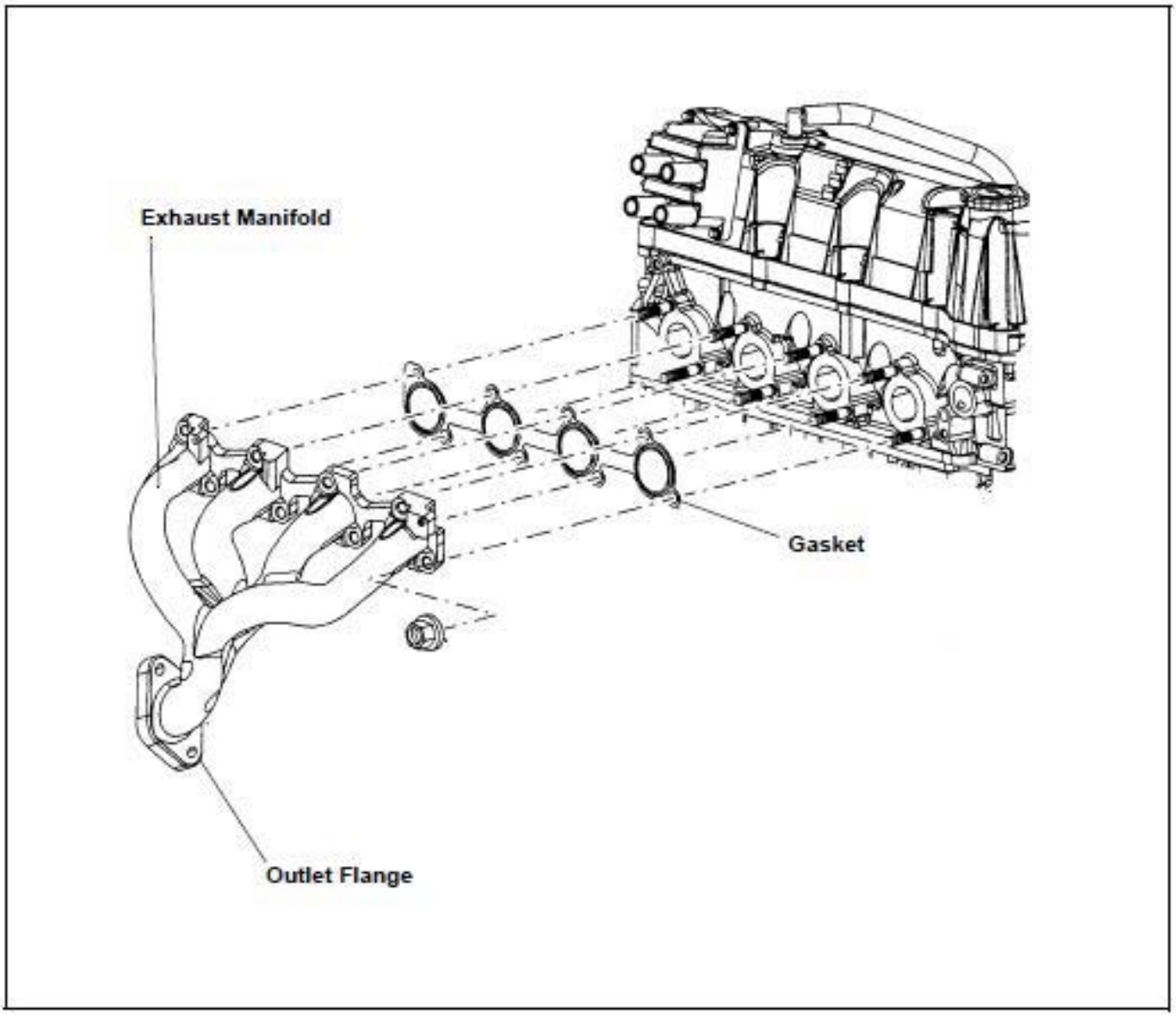
Intake Manifold - Removal

1. Remove any necessary wiring and vacuum hoses. Mark connections and routing as necessary to assure they are returned as they were removed.
2. Relieve fuel pressure.
3. Disconnect fuel lines from fuel rail.
4. Disconnect air intake tube.
5. Remove bolts, nuts and intake manifold assembly.

Intake Manifold - Installation

NOTE: All contact surfaces must be clean and free from any old gasket material.

1. Install a new gasket and intake manifold assembly.
2. Install bolts and nuts. Tighten to 6 lb.ft. (8 Nm).
3. Connect air intake tube.
4. Connect fuel lines to fuel rail
5. Install any wiring and vacuum hoses that were removed. Connect and route as they were removed.



Exhaust Manifold - Removal

1. Remove any necessary wiring and vacuum hoses. Mark connections and routing as necessary to assure they are returned as they were removed.
2. Disconnect exhaust at outlet flange.
3. Remove nuts, exhaust manifold and gasket.

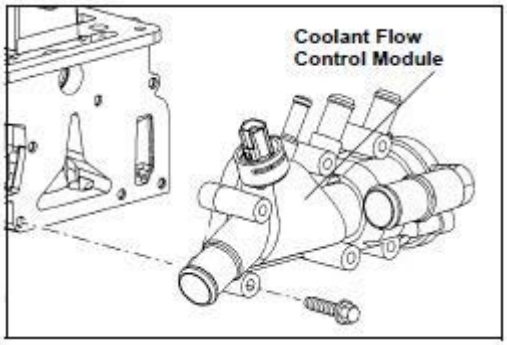
Exhaust Manifold - Installation

NOTE: All contact surfaces must be clean and free from any old gasket material.

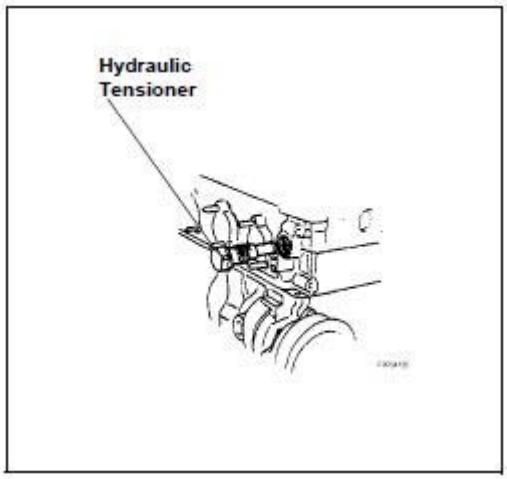
1. Install a new gasket and exhaust manifold.
2. Install nuts. Tighten to 11 lb.ft. (15 Nm).
3. Connect exhaust at outlet flange.
4. Tighten flange nuts 35 lb. ft. (47.5Nm)
5. Install any wiring and vacuum hoses that were removed. Connect and route as they were removed

Cylinder Head - Removal

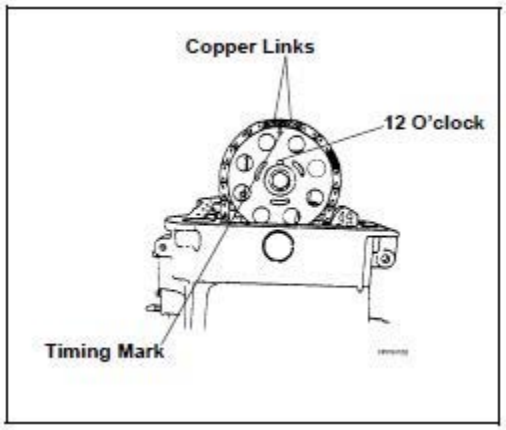
1. Drain engine oil - refer to Operator Handbook.
2. Drain engine coolant - refer to Section 05.
3. Remove any necessary wiring and vacuum hoses. Mark connections and routing as necessary to assure they are returned as they were removed.
4. Remove valve cover -- Refer to “Valve Cover - Removal” on page 10.
5. Remove spark plugs and wires.
6. Remove the coolant flow control module - refer to Section 05.



7. Remove bolts and nuts holding intake manifold to cylinder head. Move aside.
8. Remove nuts at exhaust manifold. Move aside.
9. Remove oil level indicator tube bolt at cylinder head.
10. Remove timing chain hydraulic tensioner.



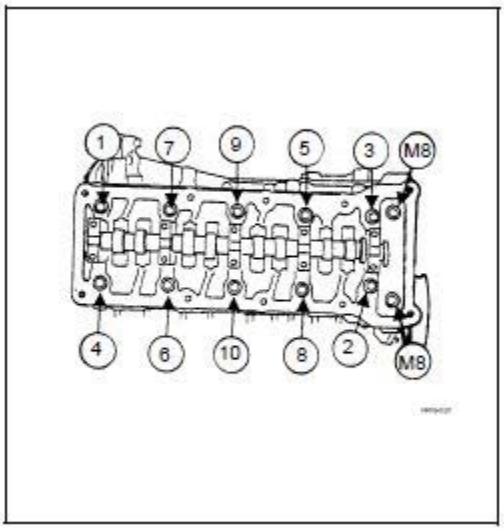
11. Rotate camshaft sprocket using tool 15-030A until the 2 copper links on timing chain are at 12 o’clock.



12. Using tool 15-030A to lock camshaft sprocket, remove bolt.

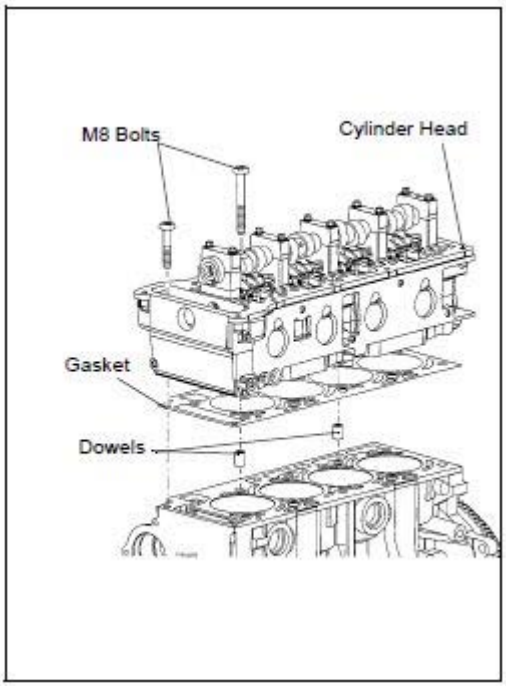
CAUTION: During cylinder head removal, the timing chain must be held up with a wire with constant tension in order to keep timing links aligned at crankshaft. If chain is allowed to slacken or disengage with sprocket, the oil pump will have to be removed, and the timing chain realigned – refer to timing chain assembly xxx.

13. Remove camshaft sprocket from chain while maintaining tension on the chain using a wire.
14. Remove the M11 cylinder head bolts in 3 phases in the sequence shown.

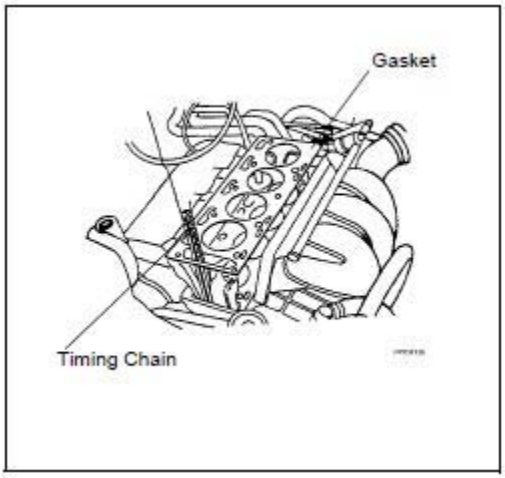


CAUTION: Be careful to avoid the bolts falling into the timing chain compartment.

15. Remove 2 M8 bolts, cylinder head and gasket.



16. Carefully remove cylinder head and gasket while maintaining tension on timing chain.



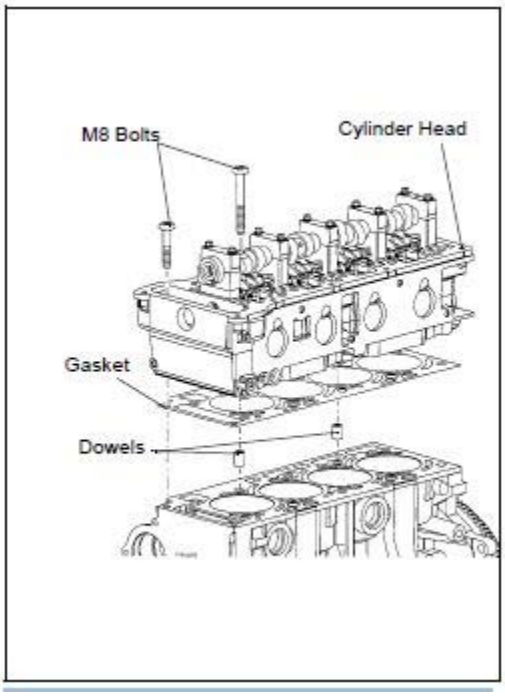
Cylinder Head - Installation

NOTE: The contact surface of the cylinder head and block must be clean and free of oil. Use new cylinder head bolts and lubricate the threads.

1. Rotate crankshaft so all pistons are **below** top dead center (TDC).

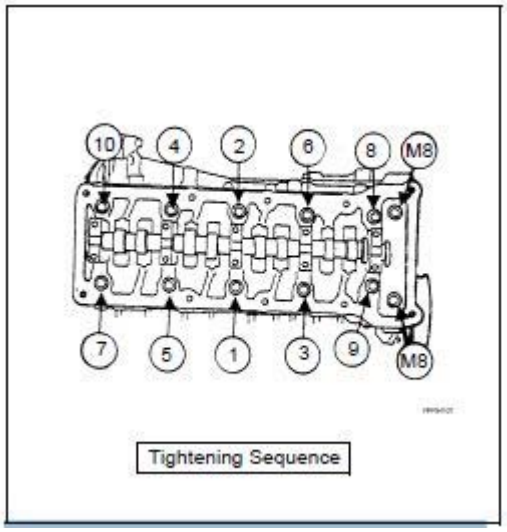
CAUTION: During cylinder head installation, the timing chain must be held up with a wire with constant tension in order to keep timing links aligned at crankshaft. If chain is allowed to slacken or disengage with sprocket, the oil pump will have to be removed, and the timing chain realigned.

2. Carefully install dowels, a new gasket and cylinder head to the engine block while maintaining tension on the timing chain.

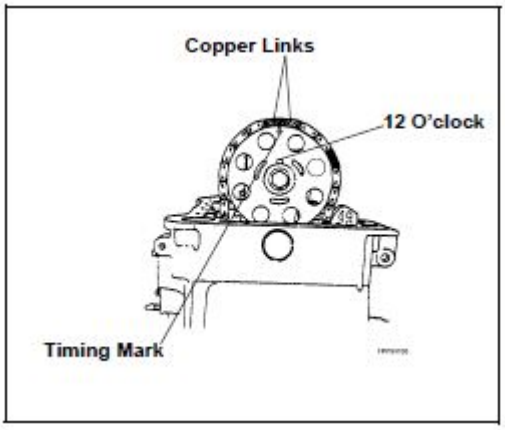


CAUTION: Be careful to avoid the bolts falling into the timing chain compartment.

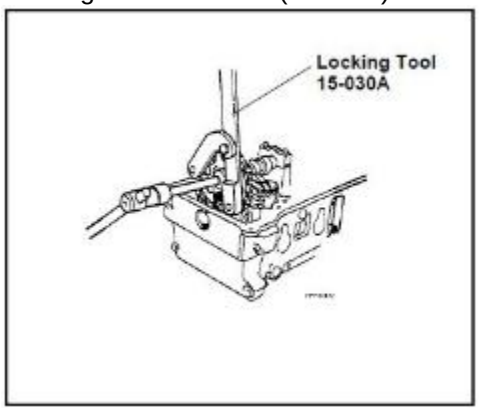
3. Install new bolts using the sequence shown in the following 3 steps:
   - Step 1 - tighten M11 bolts to 29.5 lb.ft. (40 Nm)
   - Step 2 - tighten M8 bolts to 11 lb.ft. (15 Nm) + 45
   - Step 3 - tighten M11 bolts additional 120°



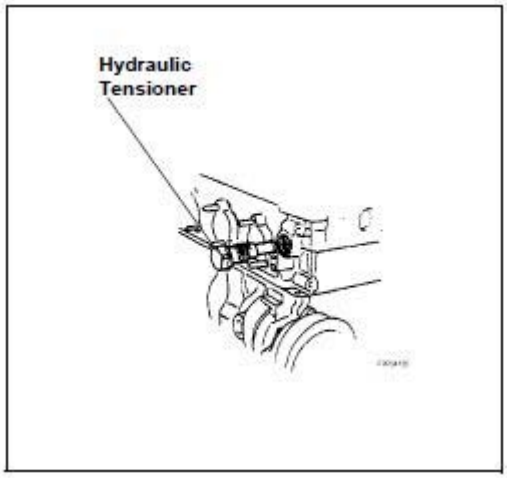
4. Carefully install sprocket into timing chain aligning timing mark with 2 copper links.



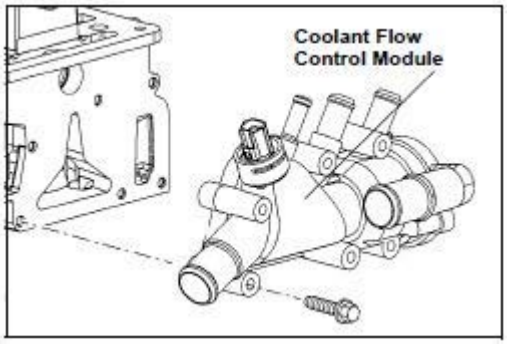
5. Using tool 15-030A, install camshaft sprocket bolt. Tighten to 92 lb.ft. (125 Nm).



6. Install hydraulic tensioner and tighten to 30 lb.ft. (40 Nm).



7. Install oil level indicator bolt. Tighten to 15 lb.ft. (20 Nm).
8. Install exhaust manifold and nuts. Tighten nuts to 11 lb.ft. (15 Nm)
9. Install bolts and nuts holding intake manifold to cylinder head. Tighten to nuts and bolts to 13 lb.ft. (18 Nm)
10. Install the coolant flow control module - refer to Section 05.

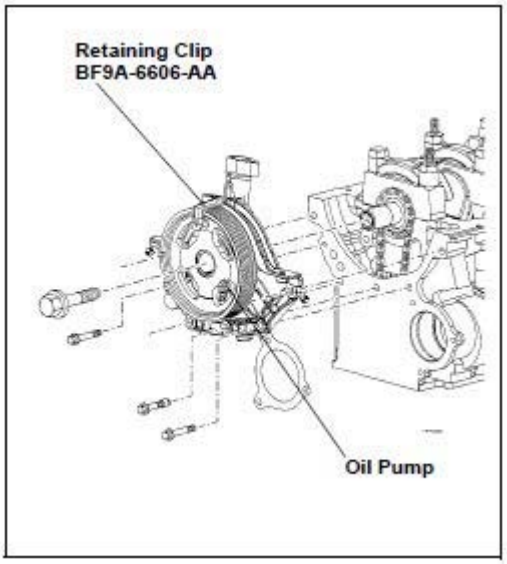


11. Install spark plugs and wires - refer to Section 03.
12. Install valve cover -- Refer to “Valve Cover - Removal” on page 10.
13. Install and route any wiring and vacuum hoses removed.
14. Fill engine with correct type and quantity of coolant - refer to Section 05.
15. Fill engine with correct type and quantity of engine oil - refer to Operator Handbook.

Oil Pump - Removal

CAUTION: The oil pump, pulley and sealer are provided as an assembly kept together by a clip (no. BF9A-6606-AA). Do not remove clip until oil pump is installed. If pulley is pushed out of the oil pump prior to oil pump installation.

1. Remove drive belt.
2. Remove water pump - refer to Section 05.
3. Insert retaining clip # BF9A-6606-AA between crankshaft pulley and oil pump to prevent pulley axial movement



4. Remove crankshaft pulley bolt.

NOTE: Identify oil pump bolts so they may be returned to their original positions.

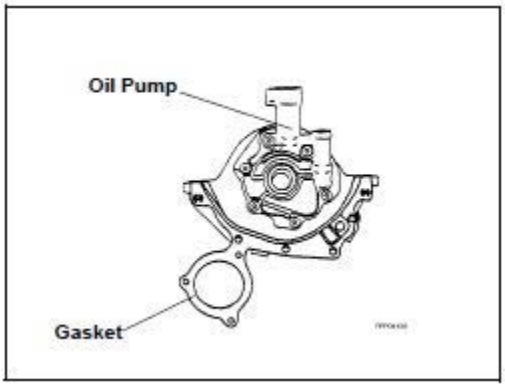
5. Remove 6 oil pump bolts, oil pump and gasket.

Oil Pump - Installation

NOTE: Contact surfaces of the oil pump and block must be clean and free of oil.

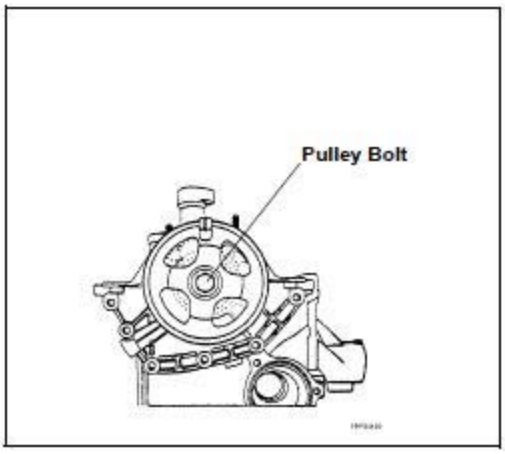
CAUTION: The oil pump, pulley and sealer are provided as an assembly kept together by a clip (no. BF9A-6606-AA). Do not remove clip until oil pump is installed. If pulley is pushed out of the oil pump prior to oil pump installation.

1. Assemble gasket onto oil pump housing guiding it with 2 outer bolts.



CAUTION: Do not apply oil to shaft or seal. Sealing lip along with all contact surfaces must be free of oil.

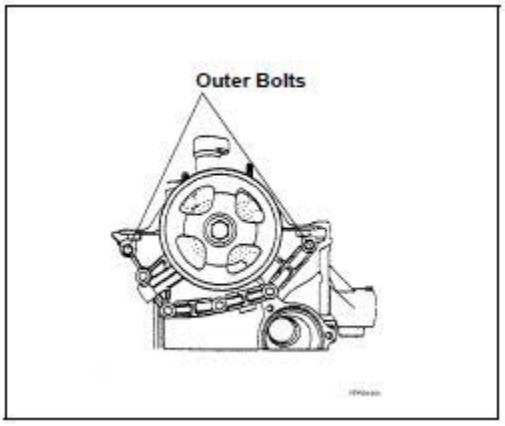
2. Place oil pump and gasket onto crankshaft.
3. Install pulley bolt and tighten to 92 lb.ft. (125 Nm).



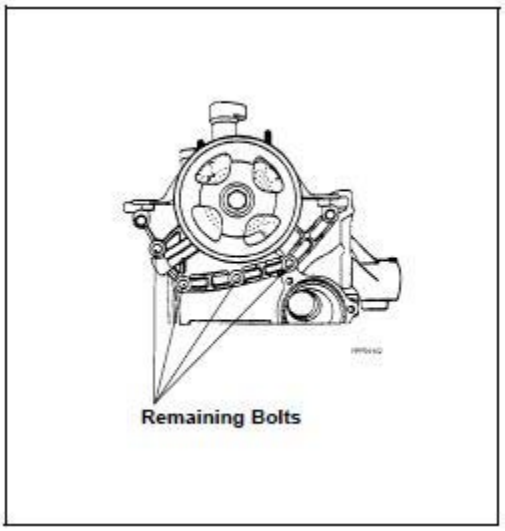
4. Remove clip.
5. Install oil pump housing bolts finger tight.

CAUTION: The oil pump housing must be positioned during tightening of the oil pump housing bolts, so that the sealing flange of the oil pump housing is within ± 0.008 in. (0.20 mm) of the block bottom sealing flanges.

6. Tighten 2 outer oil pump housing bolts to 15 lb.ft. (20 Nm).

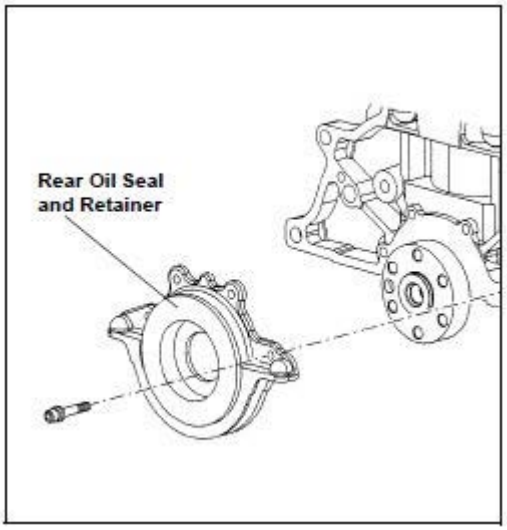


7. Tighten remaining oil pump housing bolts to 15 lb.ft. (20 Nm).



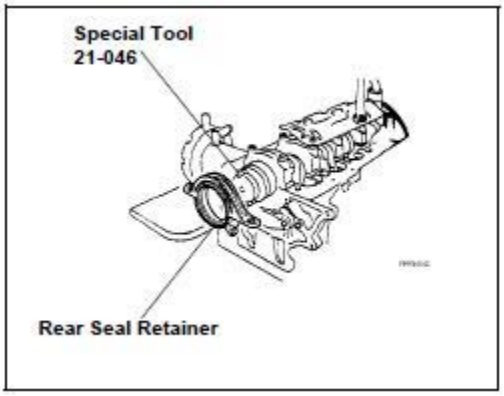
Crankshaft Rear Oil Seal – Removal

1. Remove flywheel
2. Remove oil pan
3. Remove bolts and rear oil seal retainer.



Crankshaft Rear Oil Seal - Installation

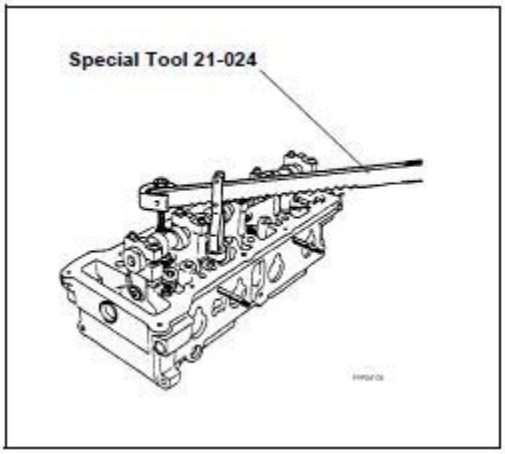
1. Install new rear seal and retainer using tool 21-046.



2. Install oil pan
3. Install flywheel

Camshaft Follower / Hydraulic Lash Adjuster – Removal

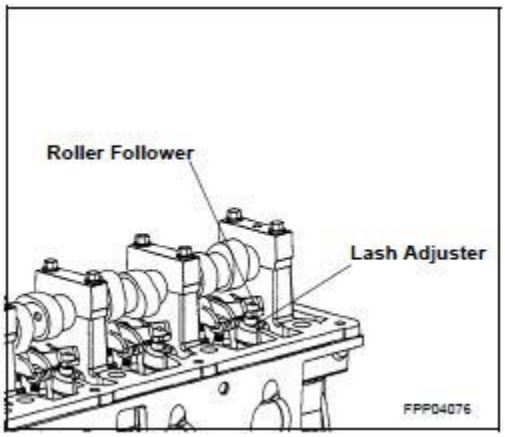
1. Remove valve cover -- Refer to “Valve Cover - Removal” on page 10.
2. Rotate the camshaft so the roller follower for the valve to be serviced is on the heel of the cam.
3. Using a suitable valve spring compressor tool, compress and hold down the valve spring. Slide out the roller follower over the lash adjuster.



4. Lift out the hydraulic lash adjuster.

Camshaft Follower / Hydraulic Lash Adjuster – Installation

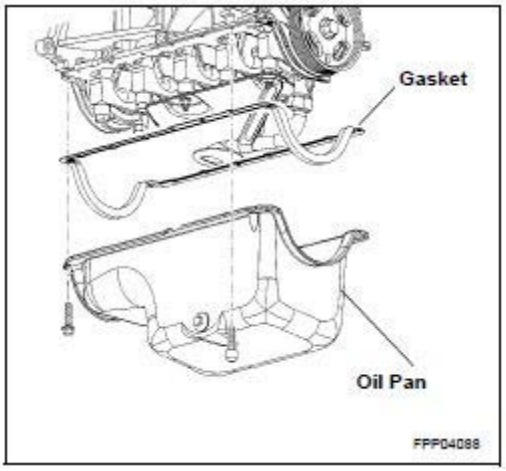
NOTE: All components must be kept clean and lubricated with clean engine oil.



1. Rotate the camshaft so the roller follower for the valve to be serviced is on the heel of the cam.
2. Install the hydraulic lash adjuster.
3. Using a suitable valve spring compressor tool, compress and hold down the valve spring. Slide in the roller follower over the lash adjuster.
4. Install valve cover -- Refer to “Valve Cover - Removal” on page 10.

Oil Pan - Removal

1. Remove bolts.
2. Remove oil pan.



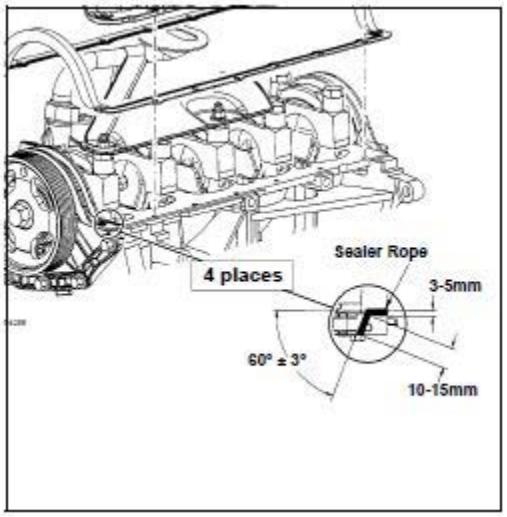
3. Remove all gasket material from pan.

CAUTION: Be careful not to contact surfaces.

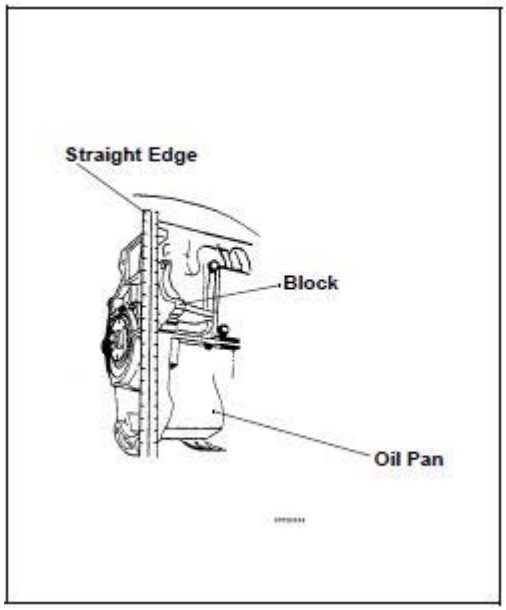
Oil Pan - Installation

CAUTION: The contact surfaces of oil pan, gasket and block must be free of oil. Do not wait more than 5 minutes to install the oil pan gasket after sealer has been applied.

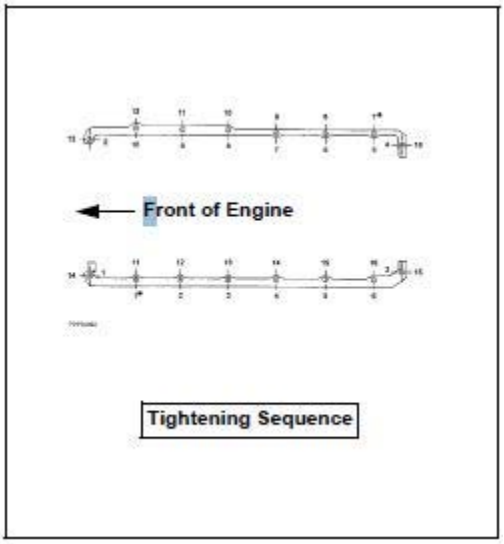
1. Apply WSEM-A4 sealer (Loctite 5910) to the 4 positions as shown.

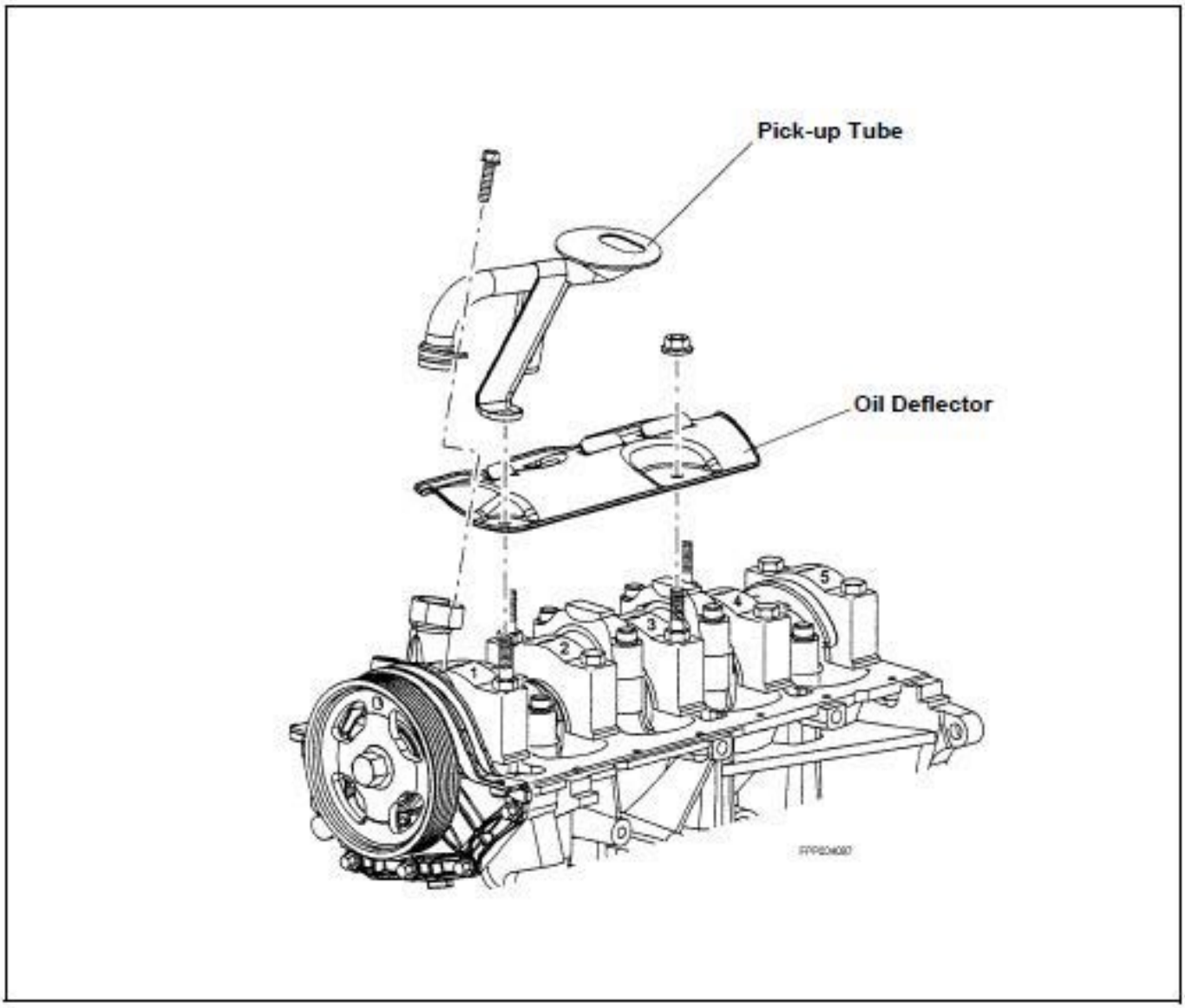


2. Install the oil pan and bolts finger tight.
3. Align oil pan with rear portion of engine block



4. Tighten oil pan bolts in 3 steps in the sequence shown:
   - enough for gasket settlement
   - 5 lb.ft. (7 Nm)
   - 7 lb.ft. (10 Nm)





Pick-up Tube / Deflector - Removal

1. Remove oil pan -- Refer to “Oil Pump - Removal” on page 21.
2. Remove 4 nuts and1 bolt.
3. Remove pick-up tube.
4. Remove oil deflector.

Pick-up Tube / Deflector - Installation

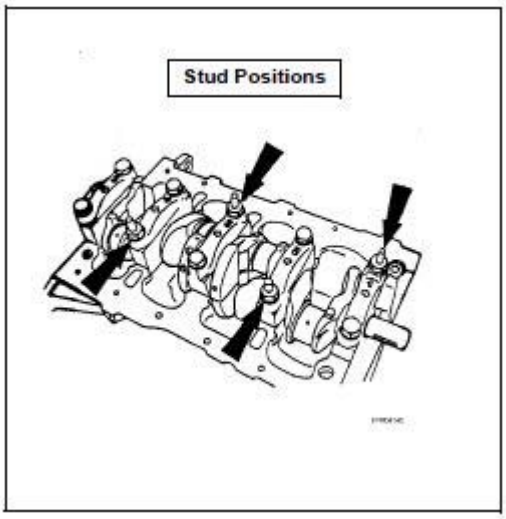
1. Install oil deflector.
2. Install pick-up tube.
3. Install 4 nuts and tighten to 14 lb.ft. (19 Nm).
4. Install bolt and tighten to 7 lb.ft. (9.5 Nm).
5. Install oil pan -- Refer to“Oil Pump - Installation” on page 22.

Crankshaft Main Bearings - Removal

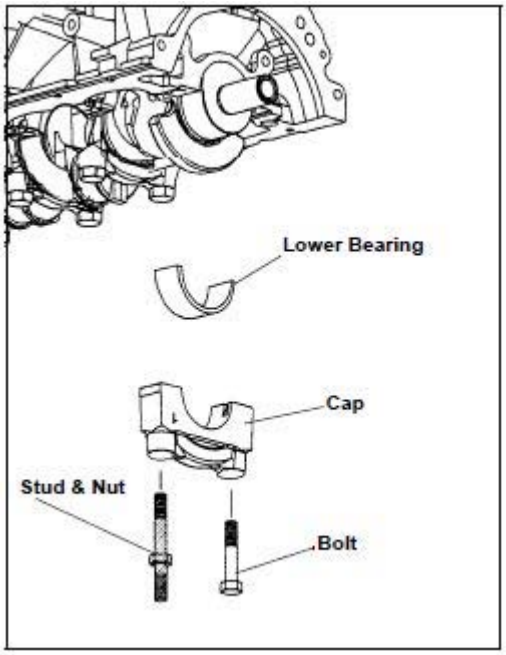
NOTE: To check bearing clearances or to select new bearings, refer to Section 01.

1. Remove oil pan -- Refer to “Oil Pan - Removal” on page 25.
2. Remove pick-up tube & deflector -- Refer to “Pick-up Tube / Deflector - Removal” on page 26.

NOTE: Replace one bearing at a time, leaving the other bearings securely fastened. Note location of studs for deflector installation.



3. Remove first main bearing cap bolts.
4. Remove cap and lower bearing.
5. Press on end of upper bearing without tang to start it out
6. Rotate bearing out from between crankshaft and cylinder block.



Crankshaft Main Bearings - Installation

NOTE: All components must be clean and dried with compressed air or a lint free cloth. Lubricate bearing to crankshaft contact surfaces with clean engine oil.

1. Place upper bearing on crankshaft and rotate into place. Oil holes must align.
2. Place lower bearing into cap.

NOTE: Main bearing cap arrow must point to the front of the engine.

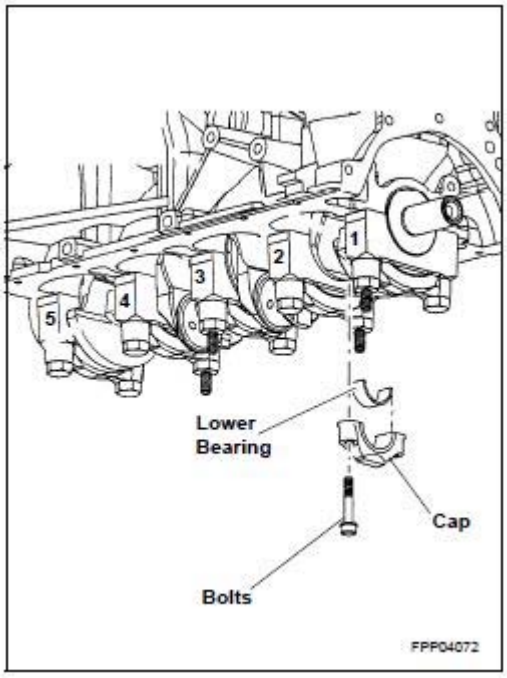
3. Install bearing cap.

CAUTION: Use new main bearing cap bolts.

4. Lightly oil new main bearing bolts or studs and install in same positions as removed. Alternately tighten in 3 steps to 70 lb.ft. (95 Nm).
5. Check crankshaft end play as outlined in Section 01
6. Install pick-up tube and deflector -- Refer to “Pick-up Tube / Deflector - Installation” on page 26.
7. Install oil pan -- Refer to “Oil Pan - Installation” on page 25.

Connecting Rod Bearings – Removal

1. Remove oil pan -- Refer to “Oil Pan - Removal” on page 25.
2. Remove pick-up tube and deflector -- Refer to “Pickup Tube / Deflector - Removal” on page 26.
3. Remove spark plug for cylinder being serviced.
4. Rotate crankshaft until connecting rod and bearing to be serviced is placed at the bottom of its stroke.
5. Remove two connecting rod nuts.
6. Remove connecting rod cap with lower bearing.



7. Push piston and connecting rod assembly up into bore.
8. Remove upper bearing from connecting rod.

NOTE: For bearing service refer to Section 01.

Connecting Rod Bearings - Installation

NOTE: Make sure bearing bore of connecting rod and cap and bearing journal are clean. Lubricate wear surfaces with clean engine oil.

1. Insert upper bearing into connecting rod.
2. Insert lower bearing into cap.

CAUTION: Do not scratch journal with connecting rod bolts.

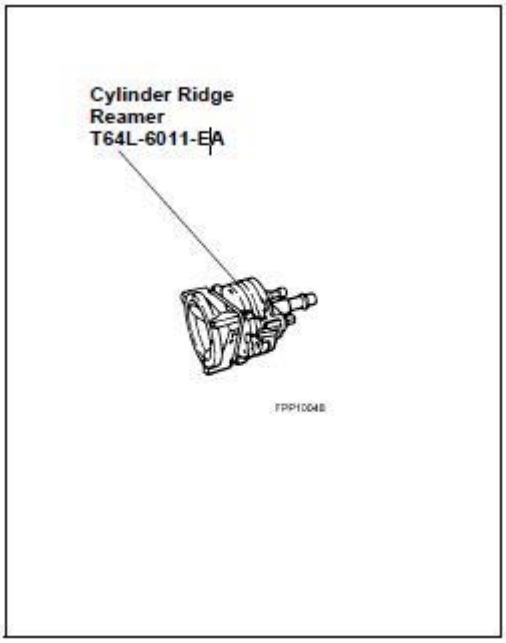
3. Install cap and bolts. Tighten bolts in 2 steps:
   - Step 1 - 9 lb.ft. (12.5 Nm)
   - Step 2 - 22 lb.ft. (30 Nm) (41-94°???)
4. Install deflector and pick-up tube -- Refer to “Pick-up Tube / Deflector - Installation” on page 26.
5. Install oil pan -- Refer to “Oil Pan - Installation” on page 25.

Piston – Removal

1. Remove oil pan -- Refer to “Oil Pan - Removal” on page 25.
2. Remove pick-up tube and deflector -- Refer to “Pickup Tube / Deflector - Removal” on page 26.
3. Remove cylinder head assembly -- Refer to Cylinder Head - Removal” on page 17.

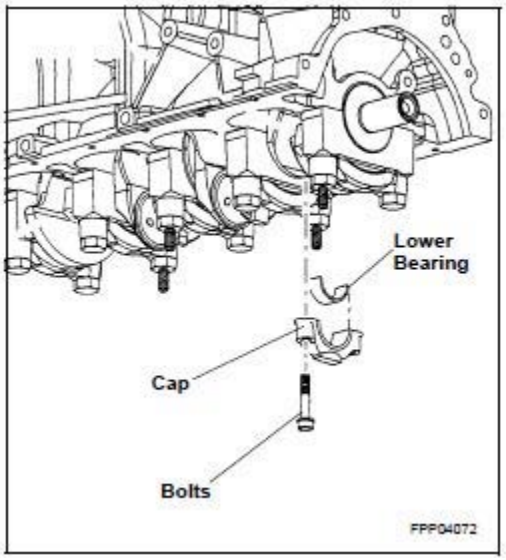
CAUTION: Never cut into the ring travel area in excess of 0.8mm (1/32 inch) when removing ridges.

4. Turn crankshaft until piston to be removed is at the bottom of its travel and place a cloth on the piston head to collect the cuttings.
5. Remove any ridge and/or deposits from the upper end of the cylinder bores using a ridge cutter. Follow the instructions furnished by the tool manufacturer.



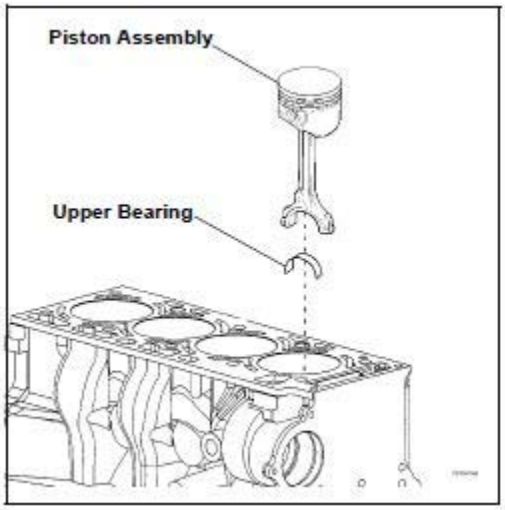
NOTE: Make sure all caps are marked so that they can be installed in their original positions.

6. Remove 2 bolts, connecting rod cap and lower bearing.



CAUTION: Avoid damage to the crankshaft journal or the cylinder wall when removing the piston and rod.

7. Push piston assembly out the top of the cylinder with the handle end of a hammer.



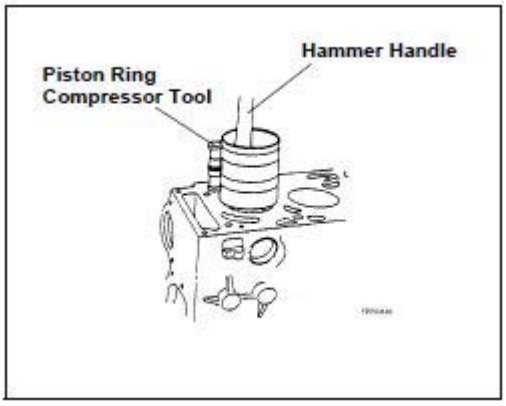
8. Remove upper bearing from connecting rod.

NOTE: For piston and bearing service - refer to Section 01.

Piston - Installation

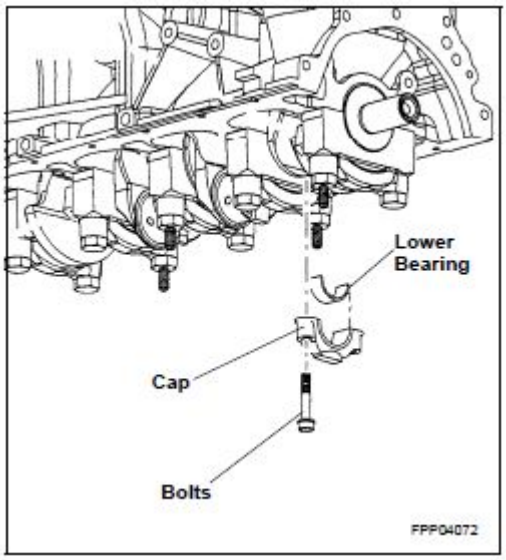
NOTE: Crankshaft journal should be at its lowest point. All components should be clean and dried with compressed air or a lint free cloth.

1. Set piston ring gaps as follows:
   - lower oil ring gap aligned with piston pin.
   - center ring gap at 90° from the oil ring gap.
   - top ring gap at 180° from the oil ring gap.
2. Lubricate piston, bearing wear surface, crankshaft journal and cylinder wall with clean engine oil.
3. Carefully install pistons with bearings into cylinder bores using a piston ring compressor and a hammer handle. Avoid damage to the crankshaft bearing journals. The arrow of the piston must point to the front of the engine. The connecting rod has the cylinder number identified in the base.



CAUTION: Use new connecting rod cap bolts and lubricate threads with clean engine oil.

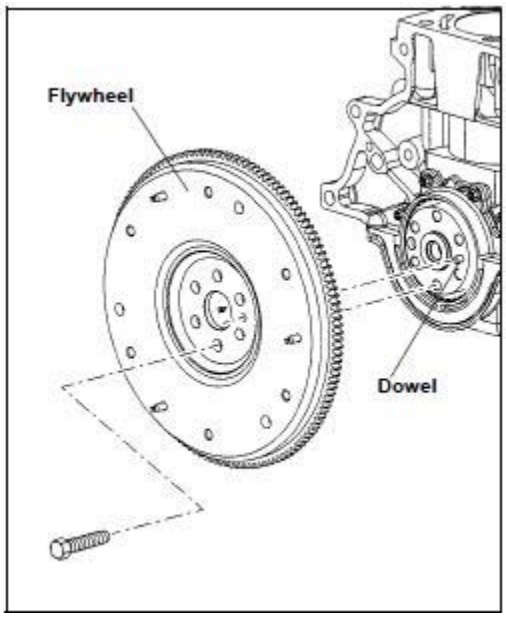
4. Install connecting rod caps with bearings (lubricate wear surface) and tighten bolts in 2 steps:
   - Step 1 - 9 lb.ft. (12.5 Nm)
   - Step 2 - 22 lb.ft. (30 Nm)



5. Check connecting rod side clearance
6. Install cylinder head assembly -- Refer to “Cylinder Head - Installation” on page 19.
7. Install pick-up tube and deflector -- Refer to “Pick-up Tube / Deflector - Installation” on page 26.
8. Install oil pan -- Refer to “Oil Pan - Installation” on page 25.

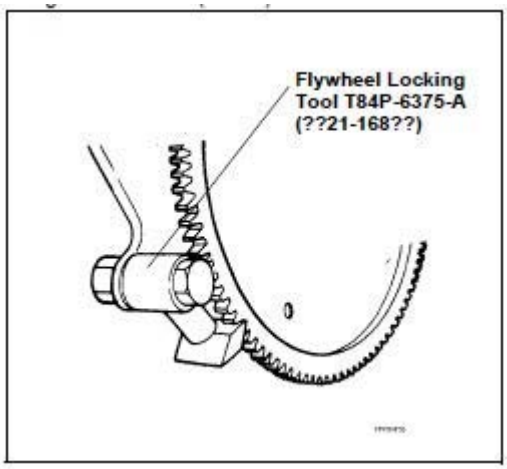
Flywheel - Removal

1. Remove bolts.
2. Remove flywheel.

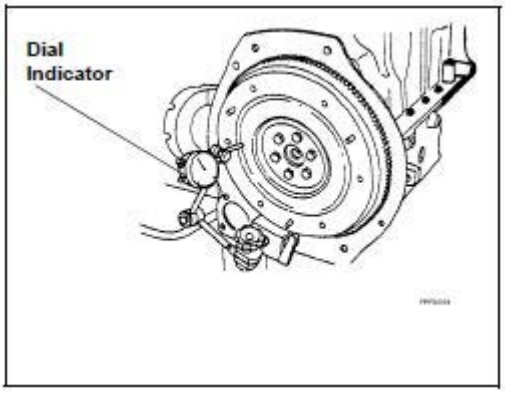


Flywheel - Installation

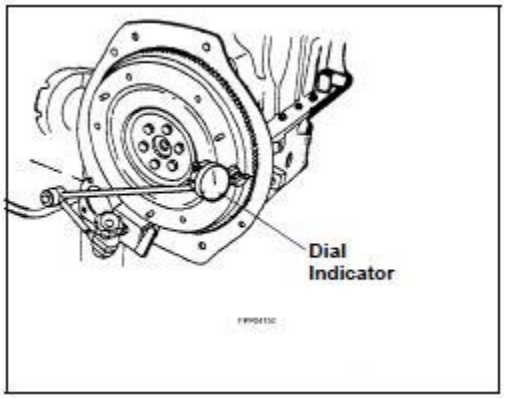
1. Install flywheel using special locking tool 21-168.
2. Lubricate bolt threads with clean engine oil and tighten to 49 lb.ft. (67 Nm).



3. Check flywheel runout at clutch disc surface:
   - maximum runout 0.005 in. (0.13 mm)

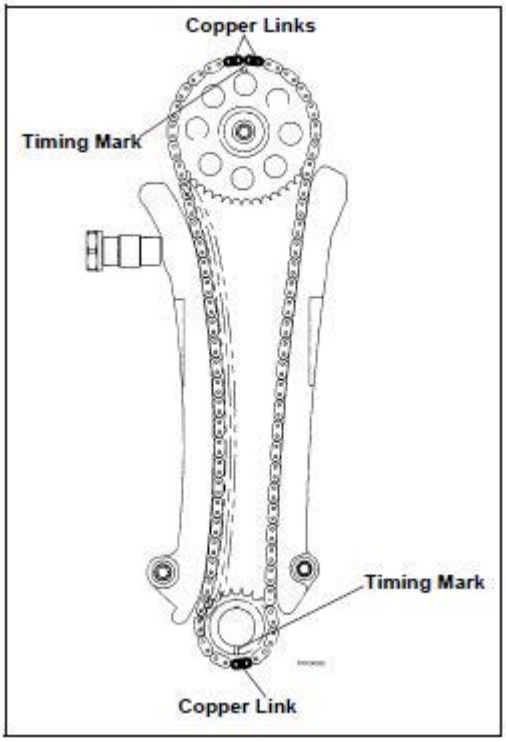


4. Check flywheel runout at gear surface:
   - maximum runout 0.024 in. (0.6 mm)

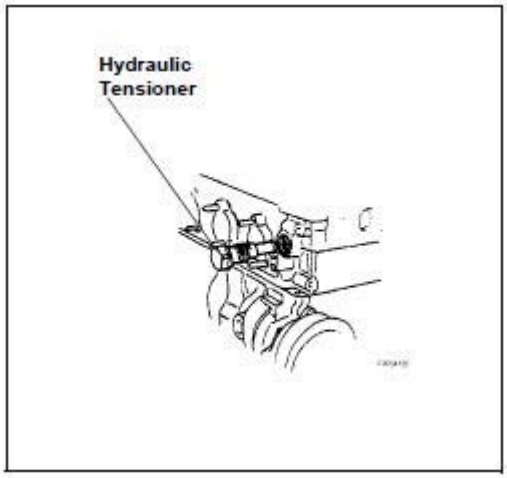


Timing Chain and Sprockets – Removal

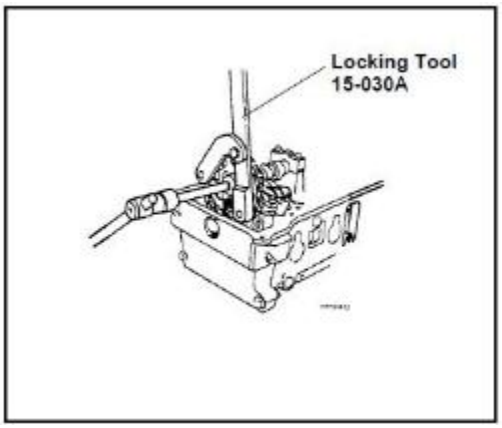
1. Remove oil pump assembly -- Refer to “Oil Pump -Removal” on page 21.
2. Remove valve cover -- Refer to “Valve Cover - Removal” on page 10.
3. Check to see if coppered links on the timing chain are still visible. If not, identify them as follows:
    - Turn engine until timing mark on camshaft sprocket is at 12 o’clock.
    - Mark the two chain links left and right of that timing mark
    - Mark the single chain link that is positioned on the crankshaft sprocket timing mark



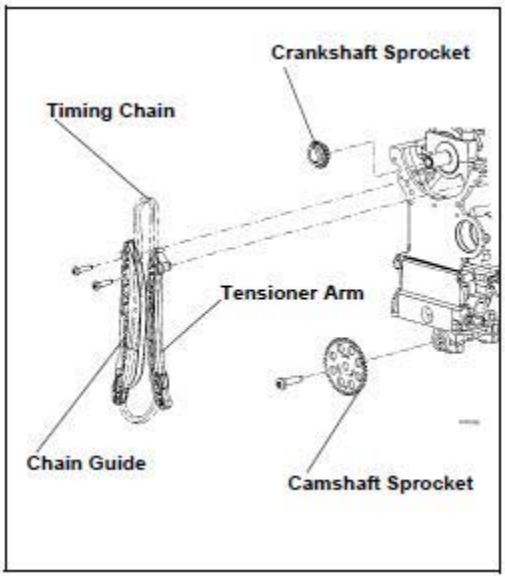
4. Remove the hydraulic tensioner.



5. Using tool 15-030A to lock camshaft sprocket, remove bolt and camshaft sprocket.



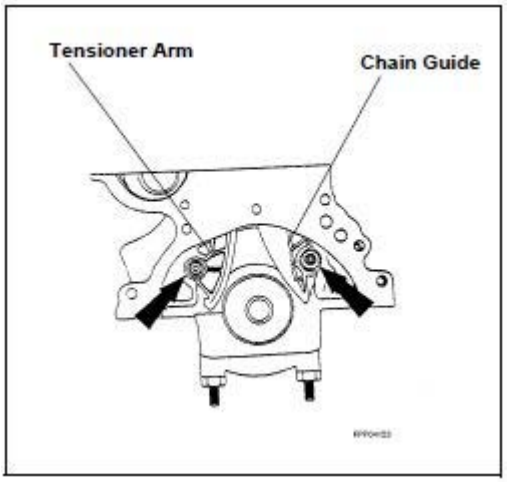
6. Remove timing chain and crankshaft sprocket.
7. Remove tensioner arm and chain guide if necessary.



Timing Chain and Sprockets - Installation

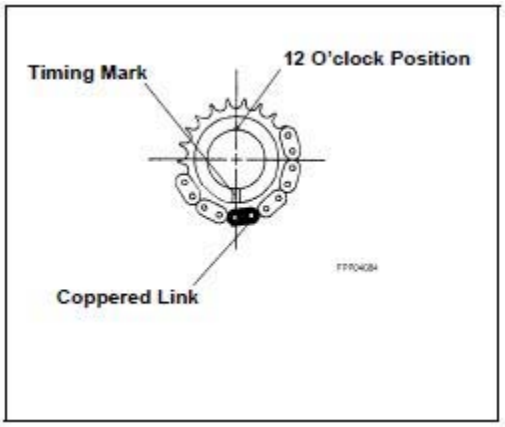
NOTE: All components must be clean and dried with compressed air or a lint free cloth. Lubricate with clean engine oil.

1. Install the (if removed) chain guide and the tensioner arm from the top of the engine. Install bolts finger tight.

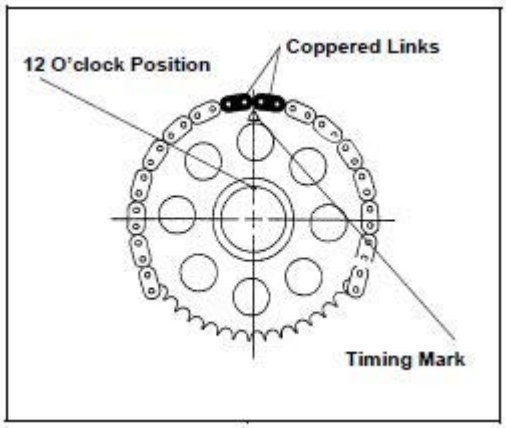


2. Install crankshaft sprocket with key at 12 o'clock position.

3. Assemble drive chain through chain housing cavity from top of engine and onto crankshaft sprocket. Align timing mark with coppered link on drive chain.

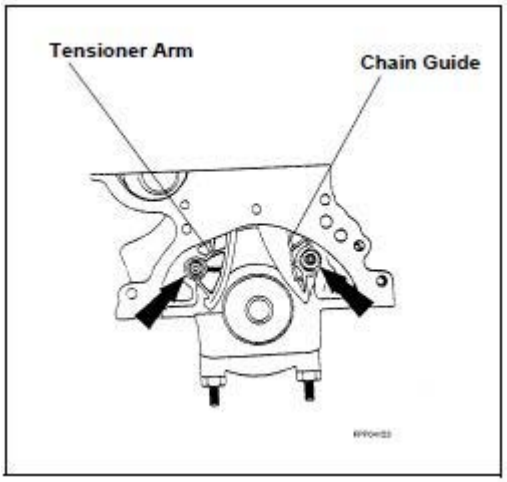


4. Insert camshaft sprocket into chain and assemble to camshaft. Position camshaft key at 12 o'clock and align timing mark between 2 coppered links on drive chain.

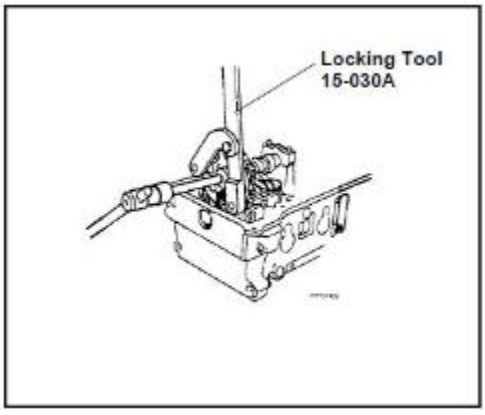


5. Install camshaft sprocket bolt and hydraulic tensioner finger tight.

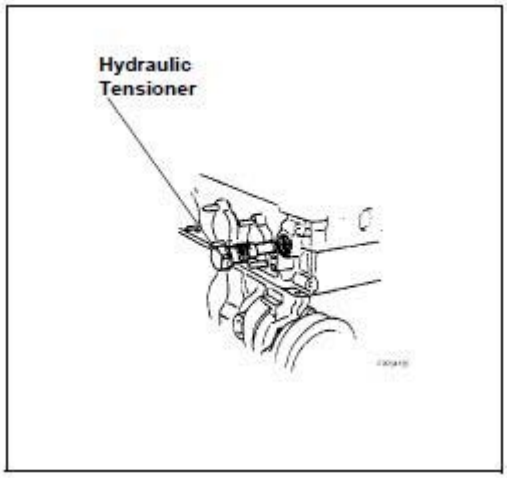
6. Tighten guide and tensioner arm bolts to 18-21 lb.ft. (24-28 Nm).



7. Using locking tool, tighten camshaft sprocket bolt to 52-59 lb.ft. (70-80 Nm).

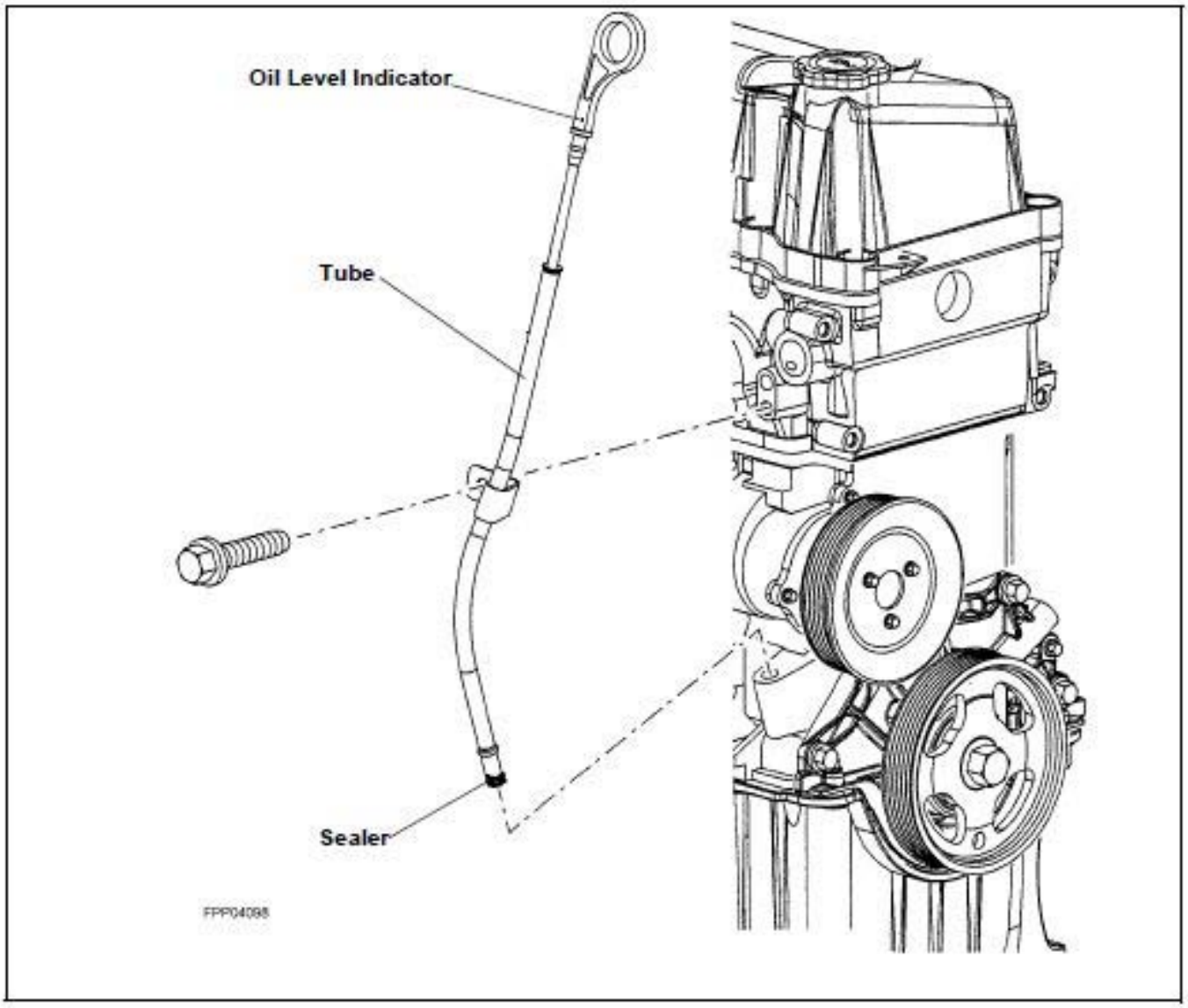


8. Tighten hydraulic tensioner to 27-32 lb.ft. (36-44 Nm).



9. Install valve cover -- Refer to “Valve Cover - Installation” on page 10.

10. Install oil pump assembly -- Refer to “Oil Pump - Installation” on page 22.



Oil Level Indicator – Removal

1. Remove bolt.
2. Remove oil level indicator & tube.

Oil Level Indicator – Installation

1. Apply sealer WSK-M2G 349-A4 (Loctite 648) to lower end of oil level indicator tube.
2. Install tube immediately into bore.
3. Install bolt and tighten to 15 lb.ft. (20 Nm).

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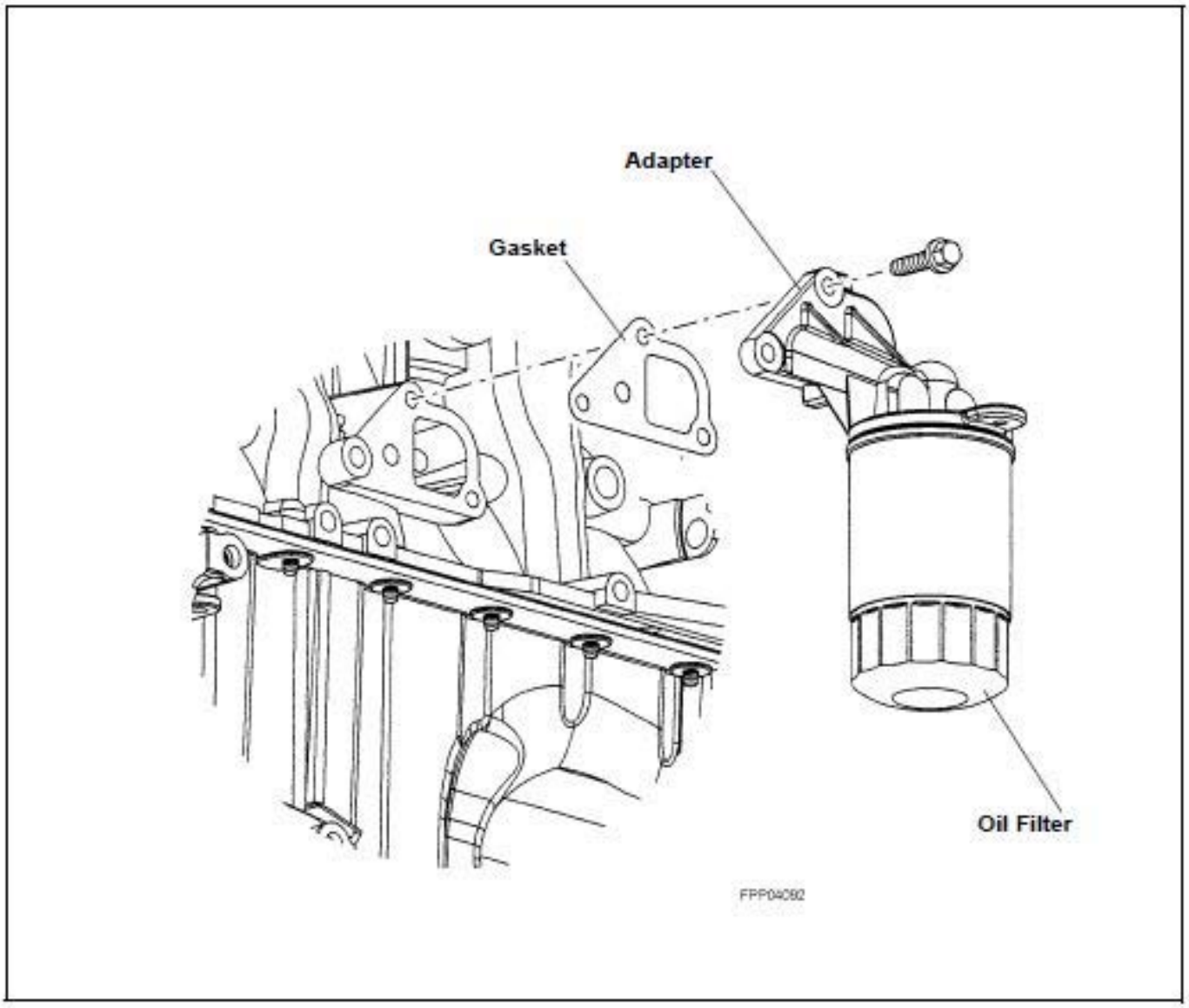


Oil Filter and Adapter - Removal

NOTE: Place oil drain pan under oil filter to catch oil drainage.

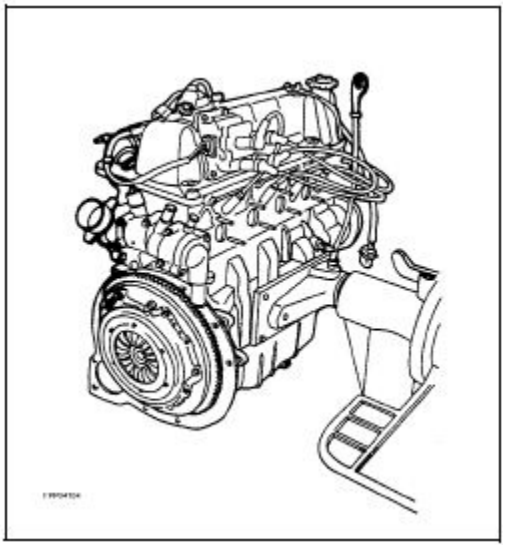
1. Remove oil filter.
2. Remove 3 bolts.
3. Remove adapter and gasket.

Oil Filter and Adapter – Installation

1. Install a new gasket.
2. Lubricate oil seal on a new filter and install to adapter. Tighten 1 1/2 to 1 3/4 turns after first contact.
3. Install filter/adapter to block.
4. Install 3 bolts and tighten to 15 lb.ft. (20 Nm).

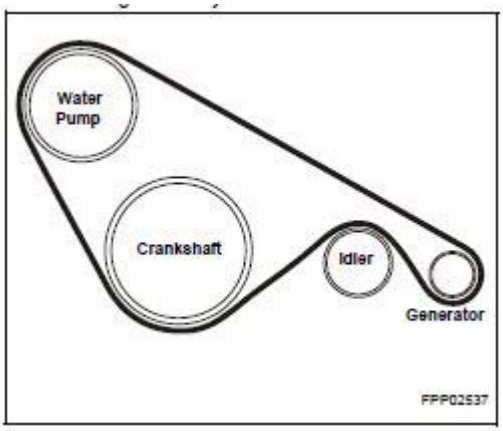
DISASSEMBLY

1. Install engine on an engine stand.

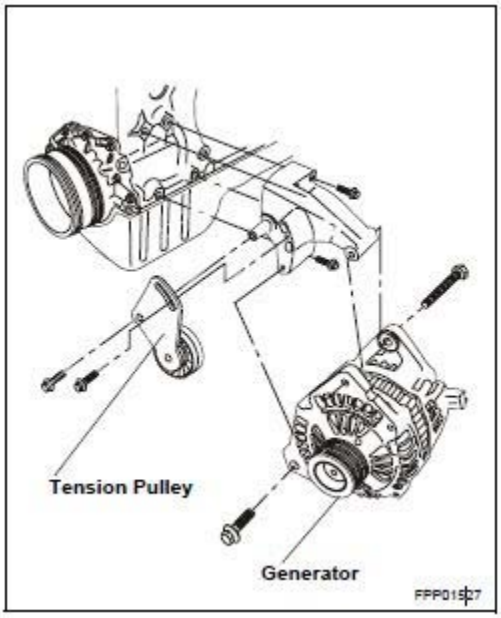


2. Drain the engine oil.

NOTE: Record drive belt routing and direction of travel for use during assembly.



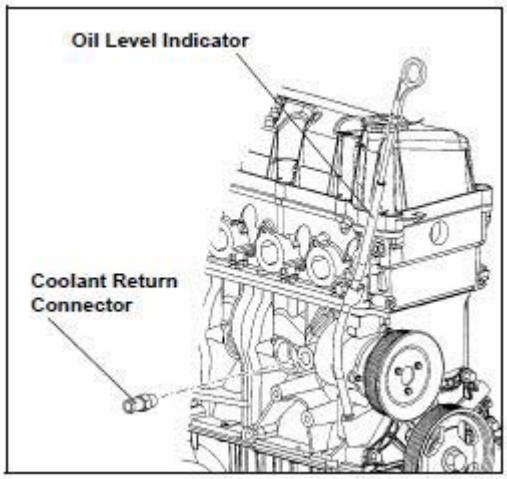
3. Loosen the tensioner pulley and remove the drive belt.



4. Disconnect wiring at generator.
5. Remove the generator.
6. Remove the generator support.

7. Remove oil level indicator tube.

8. Remove the return connector



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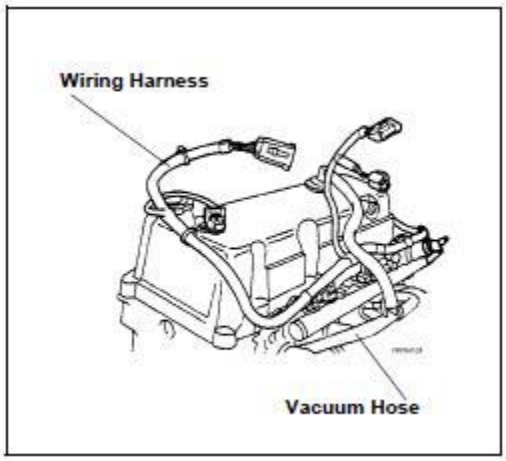
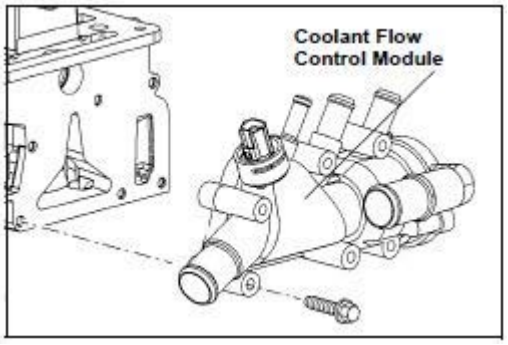
NOTE: Record routing of wiring harnesses and vacuum tubes so they may be returned to their original positions during assembly.

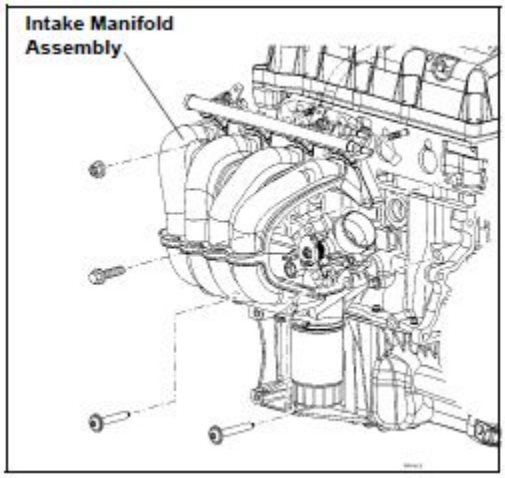
9. Remove any vacuum hoses and wiring.



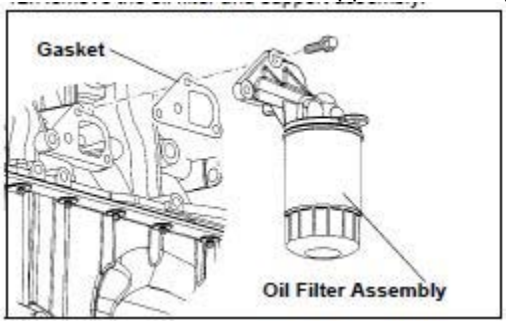
10. Remove the coolant flow control module.



11. Remove the intake manifold assembly.

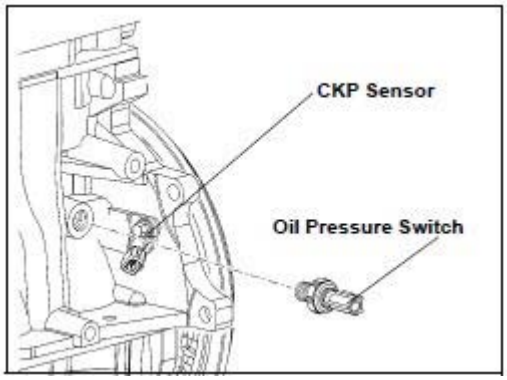


12. Remove the oil filter and support assembly.

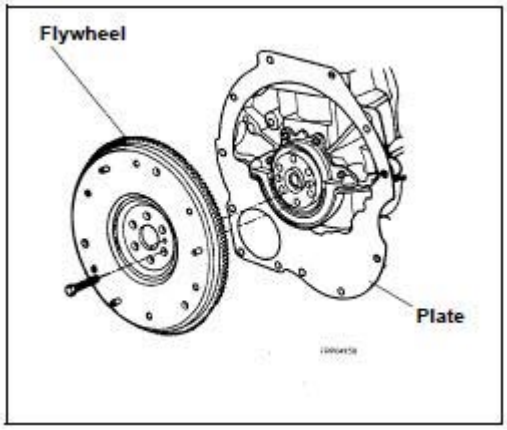


13. Remove oil pressure switch.

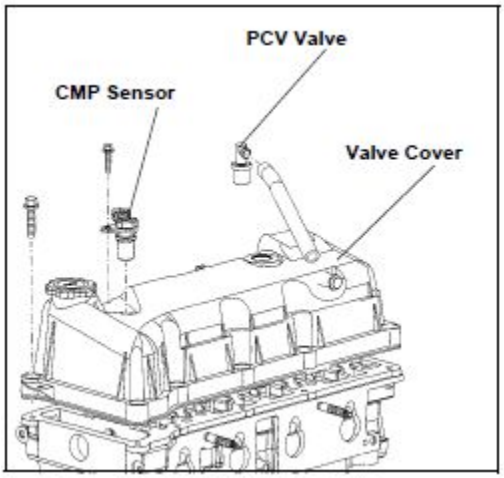
14. Remove crankshaft position (CKP) sensor.



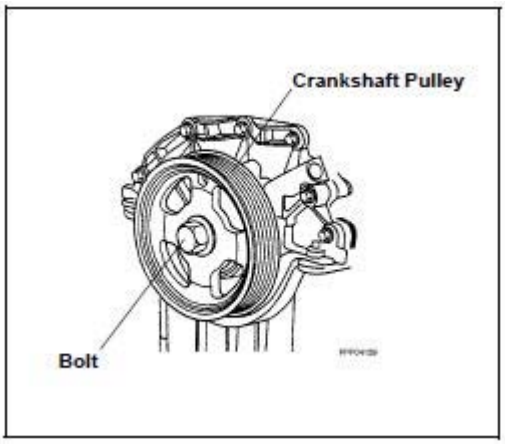
15. Remove the flywheel and flywheel plate.



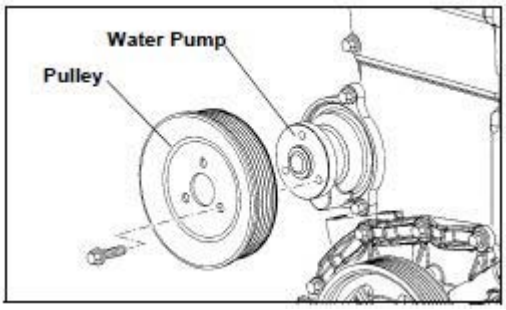
16. Remove the valve cover assembly.



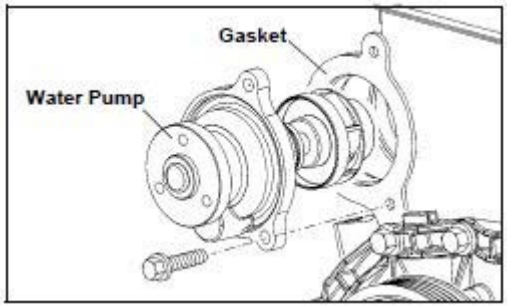
17. Loosen the crankshaft pulley bolt.



18. Remove 3 bolts and the water pump pulley.

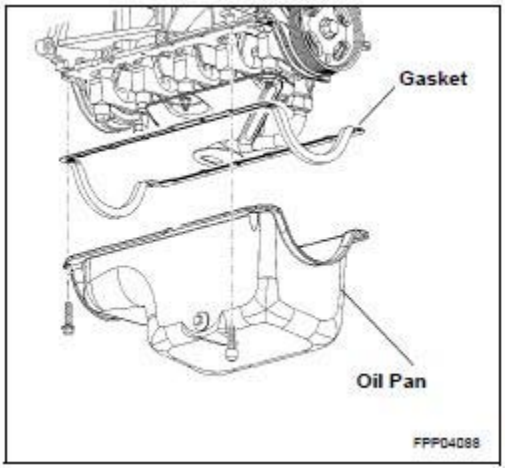


19. Remove 3 bolts, water pump and gasket.



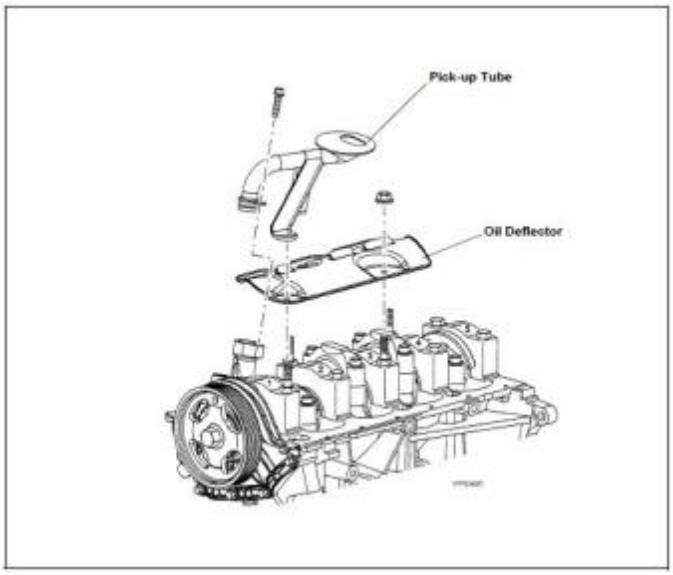
NOTE: When removing oil pan, always keep the engine in its normal upright position to avoid contamination.

20. Remove bolts, gasket and oil pan



21. Turn the engine over 180°.

22. Remove 4 nuts, 1 bolt, oil pick-up tube and oil deflector.

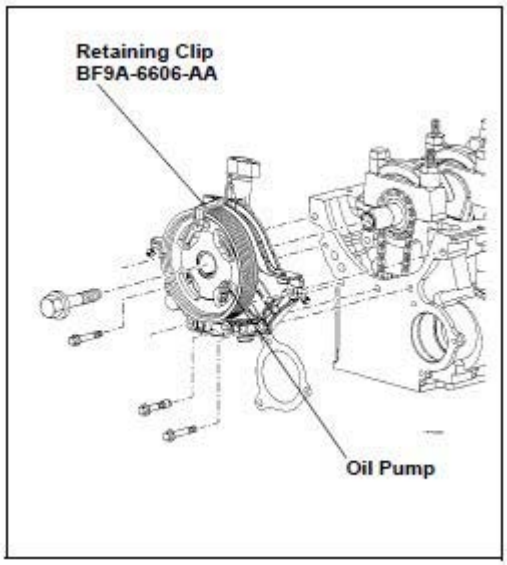


23. Insert retaining clip # BF9A-6606-AA between crankshaft pulley and oil pump to prevent pulley axial movement.

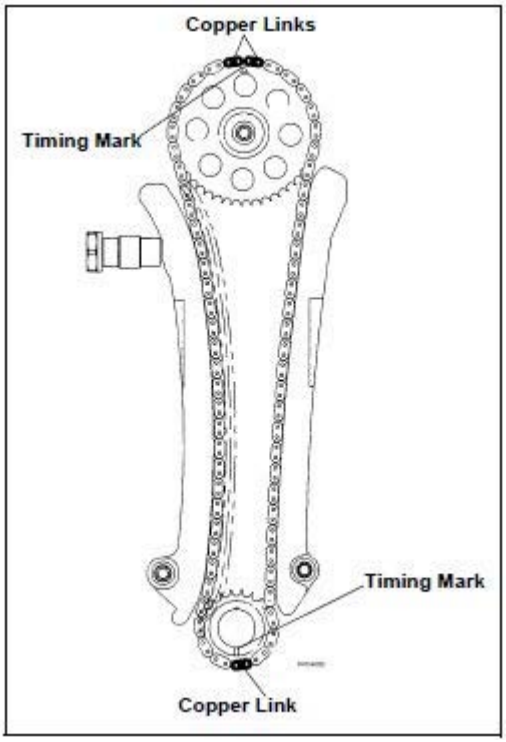
24. Remove crankshaft pulley bolt.

NOTE: Identify oil pump bolts so they may be returned to their original positions.

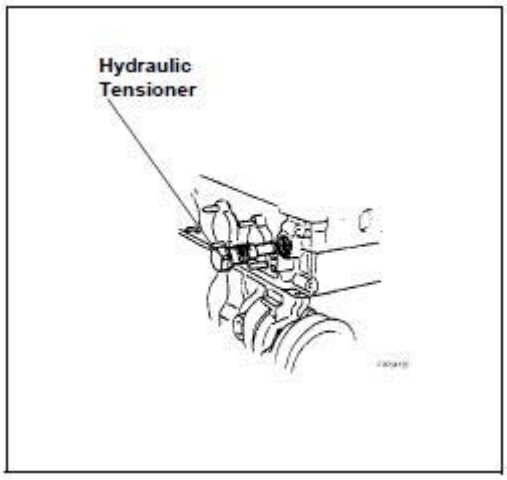
25. Remove 6 oil pump bolts, and oil pump.



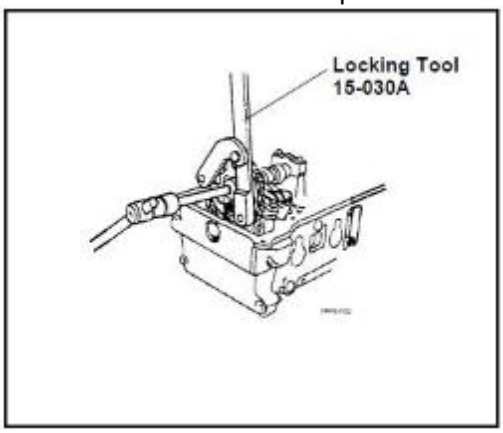
26. Check to see if coppered links on the timing chain are still visible. If not, identify them as follows:
    - Turn engine until timing mark on camshaft sprocket is at 12 o'clock.
    - Mark the two chain links left and right of that timing mark.
    - Mark the single chain link that is positioned on the crankshaft sprocket timing mark.



27. Remove the hydraulic tensioner.

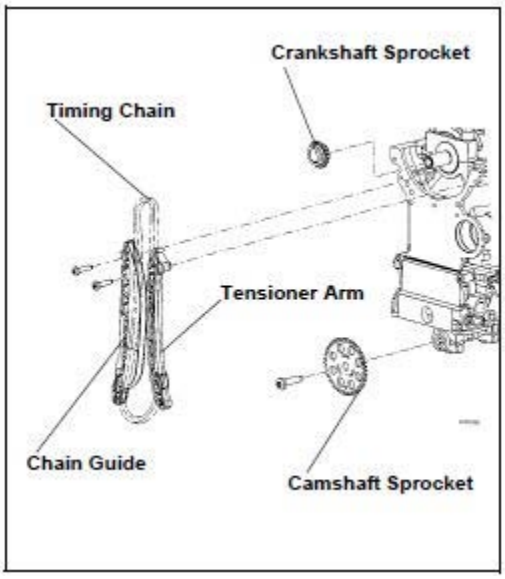


28. Using tool 15-030A to lock camshaft sprocket, remove bolt and camshaft sprocket.



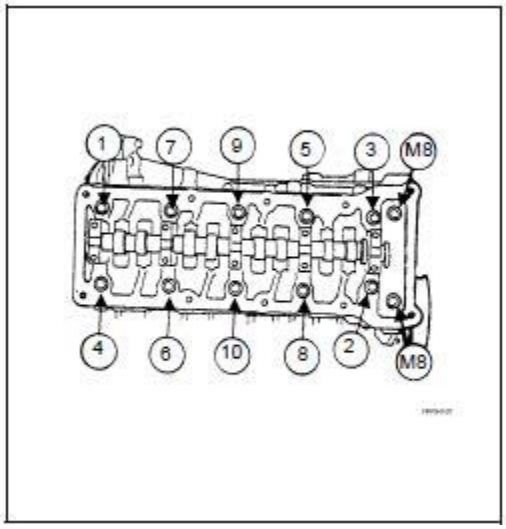
29. Remove timing chain and crankshaft sprocket.

30. Remove tensioner arm and chain guide.

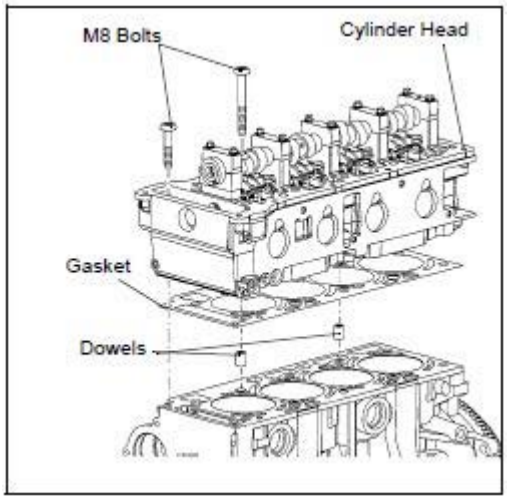


CAUTION: Keep cylinder head in the vertical position during removal to avoid warping and damage to the sealing surfaces.

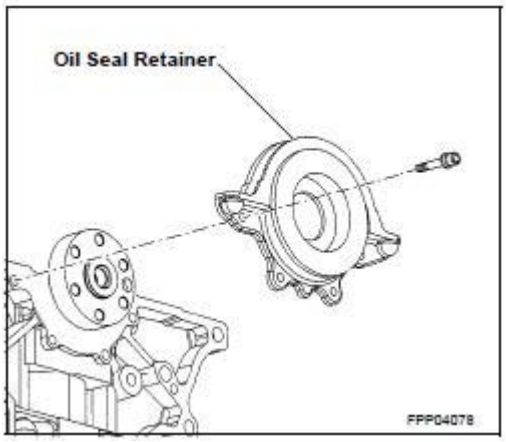
31. Remove the M11 cylinder head bolts in 3 phases in the sequence shown.



32. Remove 2 M8 bolts, cylinder head and gasket.

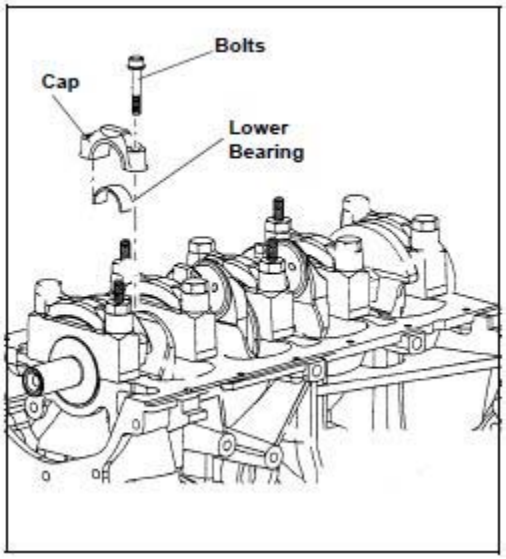


33. Remove crankshaft rear seal retainer.



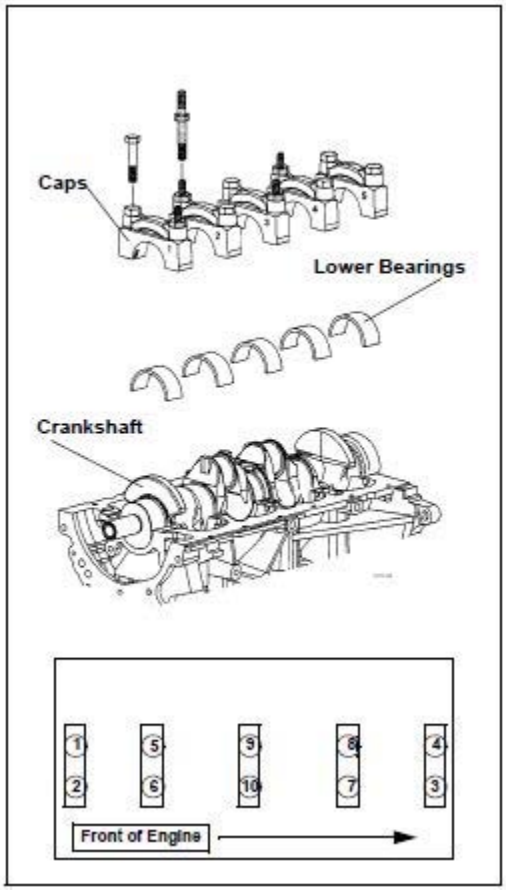
NOTE: Mark piston and cap so they may be returned to their original positions.

34. Remove 2 bolts, lower connecting rod bearing and cap. Push piston assembly out of the engine block. Repeat for other three cylinders.

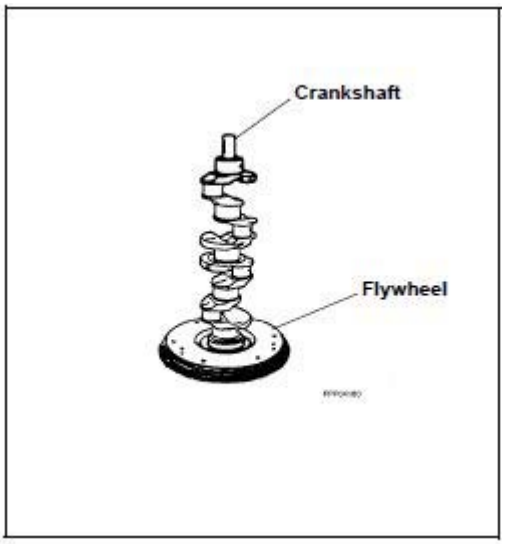


NOTE: Keep caps and bearings in order so they may be returned to their original positions.

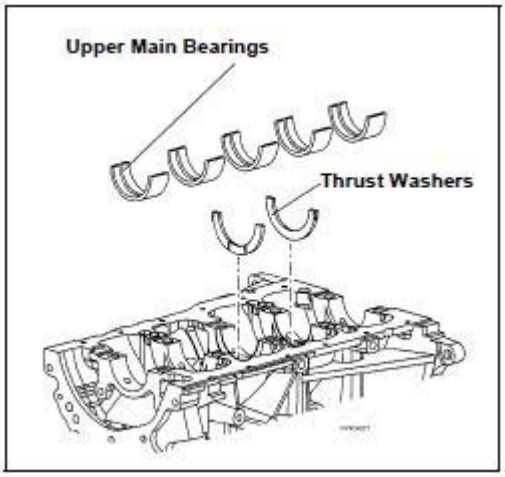
35. Remove bolts, caps and crankshaft lower main bearings in the sequence shown.



36. Carefully remove the crankshaft and install it vertically on the flywheel to avoid warp running-out.



37. Remove the 5 upper main bearings and the 2 thrust washers.



SUBASSEMBLIES

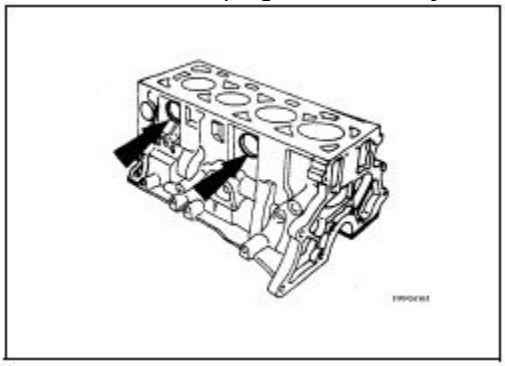
Clean crankcase and all subassemblies of all foreign material. Scrape or wire brush RTV sealant from mating surfaces. Surfaces must be kept oil free for good adhesion of fresh RTV seal (during reassembly).

NOTE: For cleaning and service information on crankcase, cylinder head, camshaft, crankshaft and bearings, Refer to Section 01.

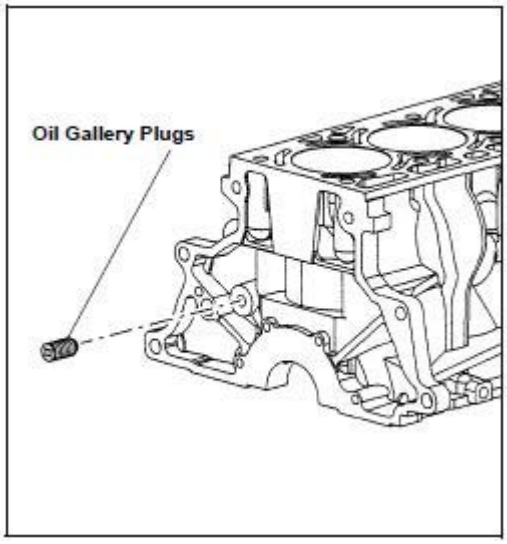
Discard gaskets and O-Rings and replace with new ones unless otherwise instructed.

Cylinder Block

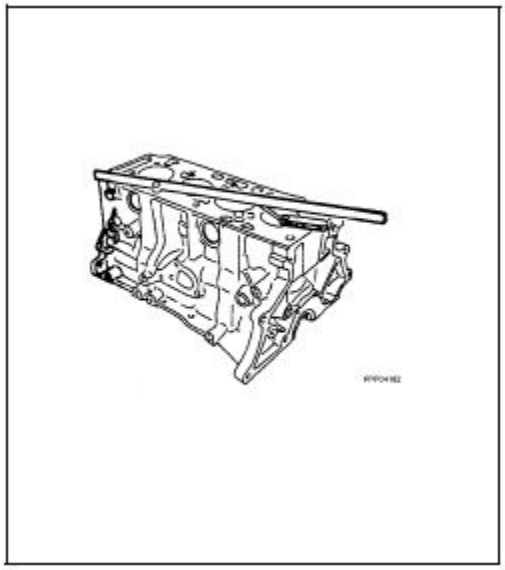
1. Remove the core plugs, if necessary.



2. Remove oil gallery plugs.



3. Check the engine block for warpage, cracks or any other damage.



4. Coolant and oil galleries must be free of dirt and deposits.

5. Refer to Section 01 for cleaning & servicing cylinder block and core plug installation.

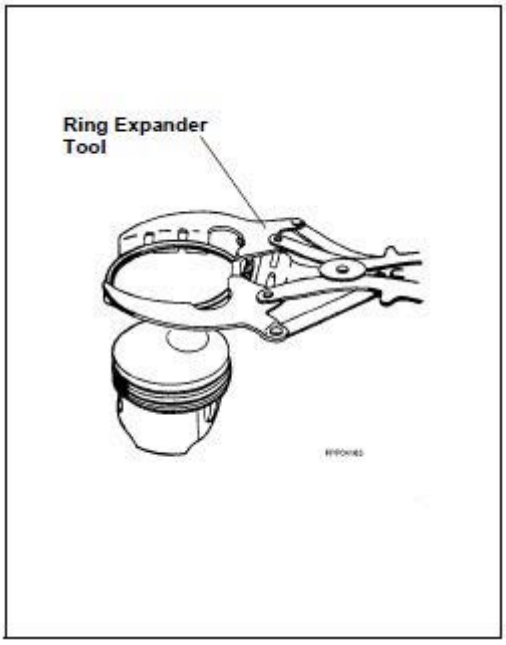
6. Reinstall oil gallery plugs.

Piston - Disassembly

NOTE: Store components to ensure assembly with the same rod and installation in the same cylinders from which they were removed. Refer to Section 01 for piston inspection and servicing.

1. Remove the connecting rod bearing from the connecting rod and cap.

2. Remove the piston rings using a suitable piston ring expander.



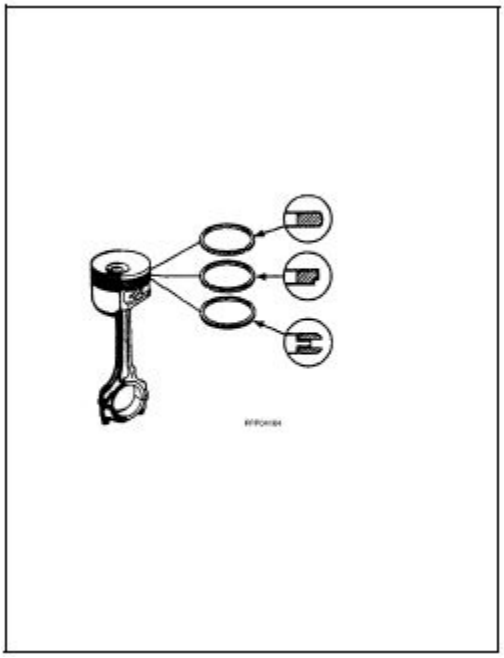
3. Remove piston pin

Piston - Assembly

NOTE: Apply a light coat of clean engine oil contact surfaces.

1. Assemble piston to connecting rod

2. Install piston rings using a suitable piston ring expander.



NOTE: Check piston ring end gap and side clearance - refer to Section 01.

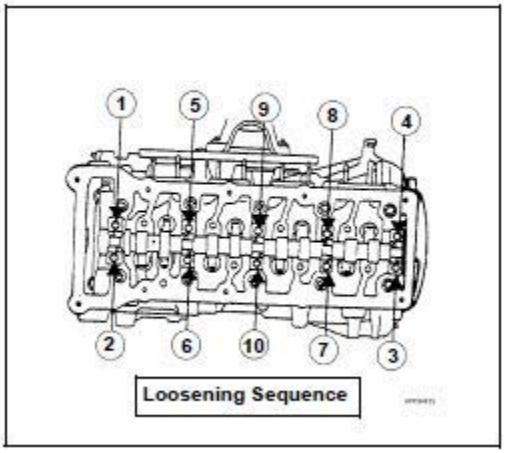
3. Install bearings into connecting rods and caps. Make sure lock slots align.

CAUTION: Make sure bearings and connecting rod bore are clean. foreign material under the inserts will distort the bearing and cause a failure.

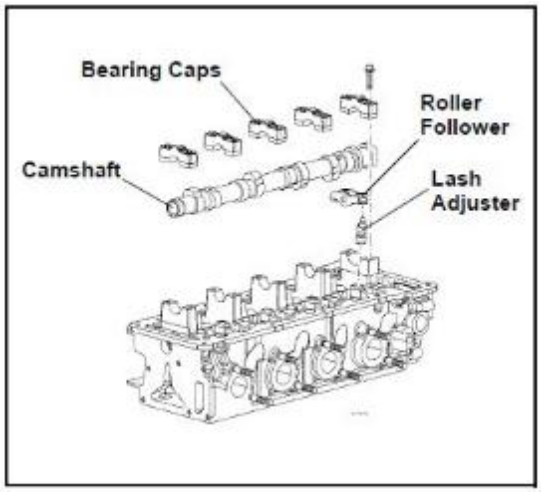
Cylinder Head - Disassembly

NOTE: Store components to ensure assembly in the same order as they were removed.

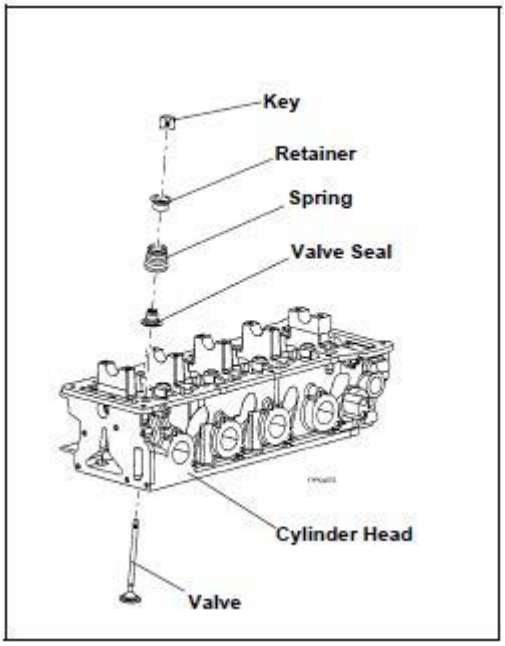
1. Remove bolts and camshaft bearing caps evenly in the sequence shown.



2. Remove camshaft.
3. Remove roller followers.
4. Remove lash adjusters.
5. Remove spark plugs.



6. Remove all valve components using a suitable valve spring compressor.



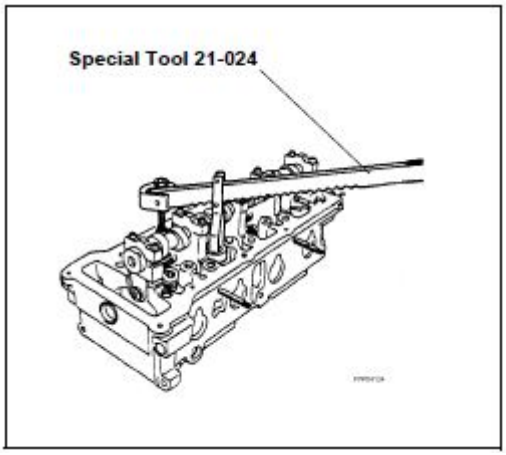
Refer to Section 01 for:

- Servicing valve components, valve guide and valve seat.
- Camshaft and bearing service.
- Cylinder head cleaning and inspection.

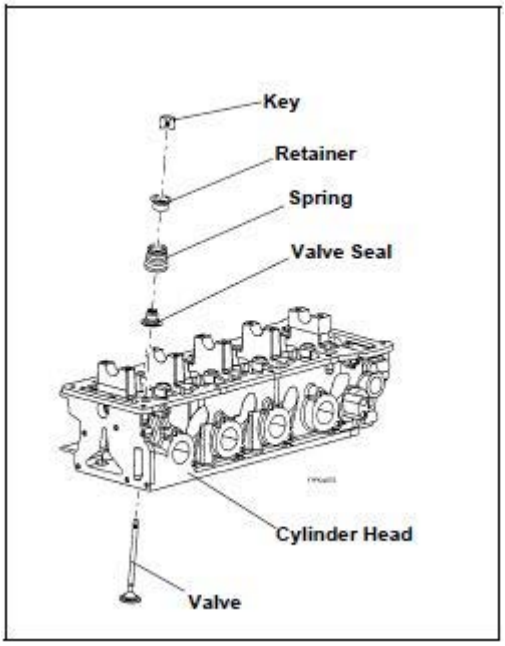
Cylinder Head - Assembly

NOTE: All components must be clean and assembled in the same positions as removed. Lubricate contact surfaces with clean engine oil.

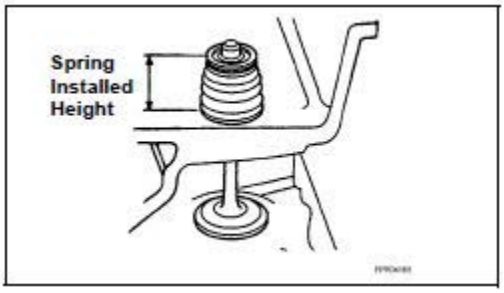
1. Check that valves move freely in valve guides.
2. Install intake and exhaust valves.
3. Install new valve seals using special tool 21-024 (optional T95P-6565A).



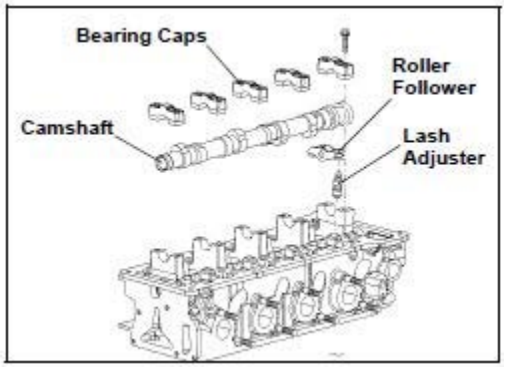
4. Using a suitable spring compressor tool, install valve springs, retainers and locks.



5. Check that spring installed height is 35.2 ± 1mm.



6. Install lash adjusters.



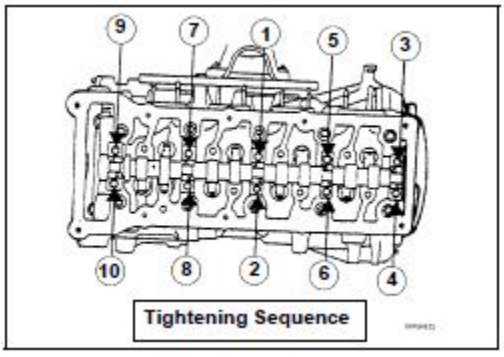
7. Install roller followers.

NOTE: The chamfer on the camshaft bearing caps must be facing the chain housing.

8. Carefully install camshaft bearings, camshaft and bearing caps with bolts finger tight.

NOTE: Rotate camshaft so key is at 12 O'clock position.

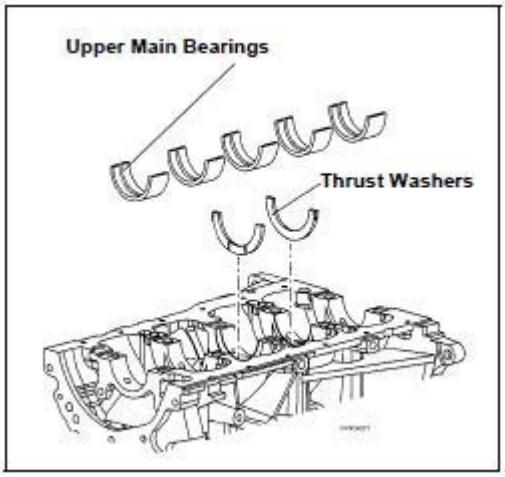
9. Tighten bolts in the sequence shown in 3 steps to 6- 7 lb.ft. (8-10 Nm).



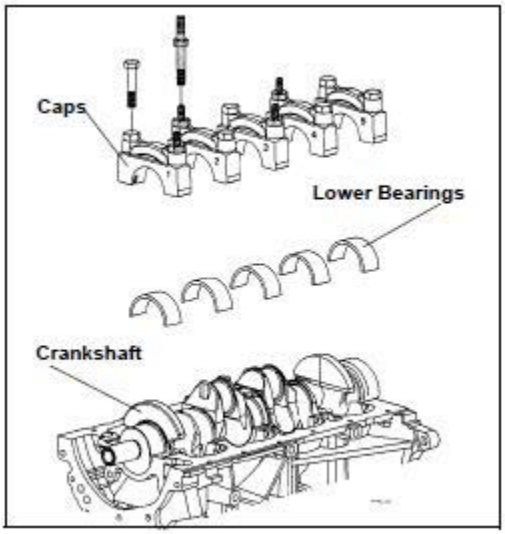
ASSEMBLY

NOTE: All components must be clean and dried with compressed air or a lint free cloth. For information on bearings & piston inspection and selection - Refer to Section 01.

1. Install upper main bearings and thrust washers to cylinder block. Lubricate the wear surfaces with clean engine oil. Make sure oil holes align



2. Carefully install the crankshaft onto the upper bearings.
3. Assemble the lower main bearings into caps. Lubricate the wear surfaces and the bolt threads with clean engine oil.

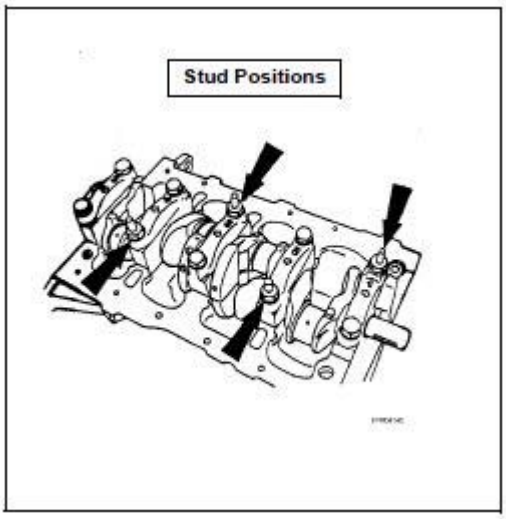


NOTE: The main bearing caps are numbered and must be assembled to corresponding numbers. The arrow on the main bearing caps must point to the front of the engine.

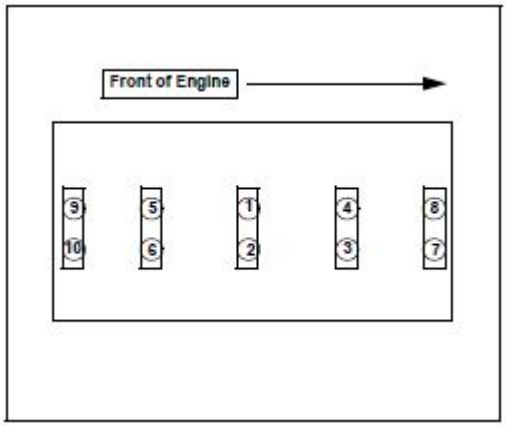
CAUTION: Use new main bearing cap bolts.

4. Install main bearing caps in the same positions as removed.

NOTE: Check the position of studs as shown.

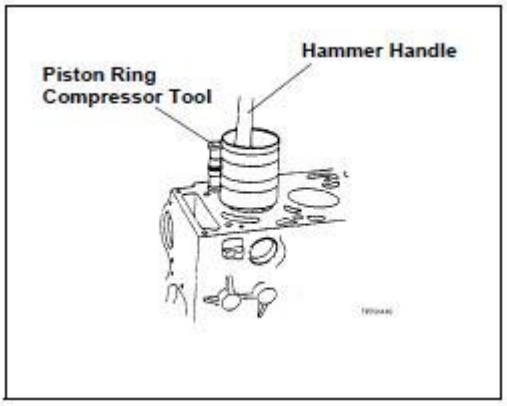


5. Tighten main bearing cap bolts/studs in sequence shown and in three steps to 70 lb.ft. (95 Nm).



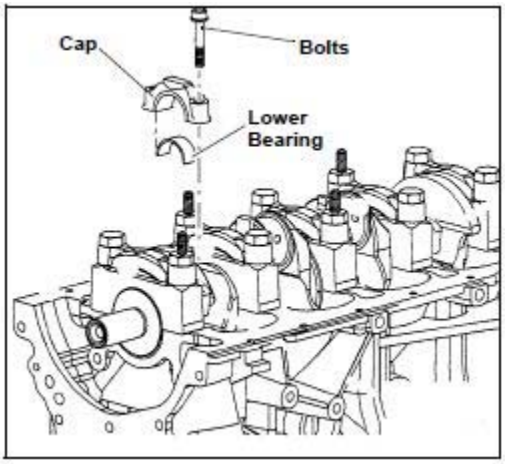
NOTE: Check crankshaft end play as outlined in Section 01.

6. Set piston ring gaps as follows:
    - lower oil ring gap aligned with piston pin
    - center ring gap at 90° from the oil ring gap.
    - top ring gap at 180° from the oil ring gap.
7. Lubricate piston, bearing wear surface, crankshaft journal and cylinder wall with clean engine oil.
8. Carefully install pistons with bearings into cylinder bores using a piston ring compressor and a hammer handle. Avoid damage to the crankshaft bearing journals. The arrow of the piston must point to the front of the engine. The connecting rod has the cylinder number identified in the base.

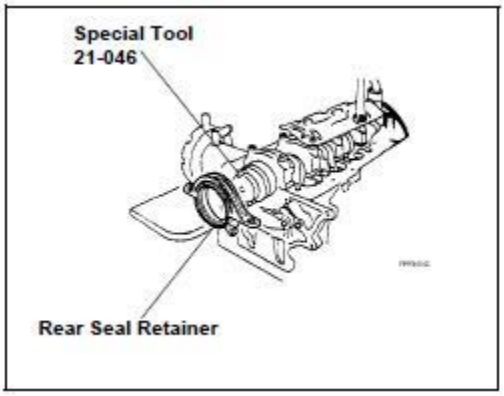


CAUTION: Use new connecting rod cap bolts and lubricate threads with clean engine oil.

9. Install connecting rod caps with bearings (lubricate wear surface) and tighten bolts in 2 steps:
    - Step 1 - 9 lb.ft. (12.5 Nm
    - Step 2 - 22 lb.ft. (30 Nm)



10. Install a new rear seal and retainer using tool 21-046.

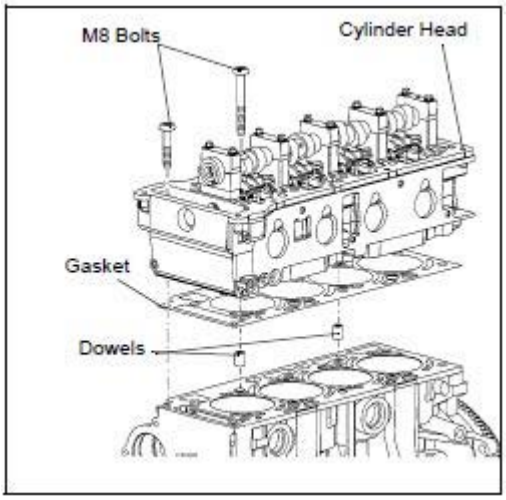


NOTE: Rear seal retainer comes on a plastic sleeve. Link plastic sleeve to crankshaft (?? 34mm ??) and push retainer to crankshaft. Plastic pins at rear side of retainer must fit to corresponding block bores. Remove plastic sleeve when done.

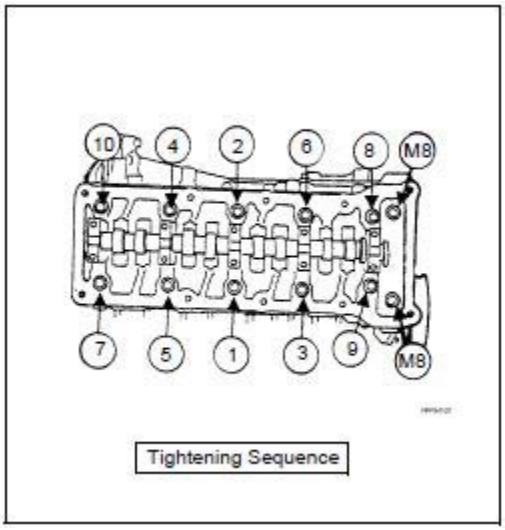
11. Turn engine 180° to prepare for cylinder head installation.

NOTE: The contact surface of the cylinder head and block must be clean and free of oil. Use new cylinder head bolts and lubricate the threads.

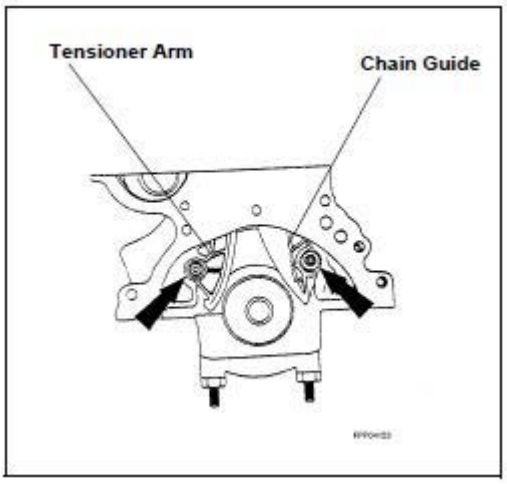
12. Rotate crankshaft so all pistons are **below** top dead center (TDC).
13. Install dowels and new cylinder head gasket to the engine block.
14. Carefully install the cylinder head onto the gasket.



15. Install new bolts using the sequence shown in the following 3 steps:
    - Step 1 - tighten M11 bolts to 29.5 lb.ft. (40 Nm)
    - Step 2 - tighten M8 bolts to 11 lb.ft. (15 Nm) + 45
    - Step 3 - tighten M11 bolts additional 120°

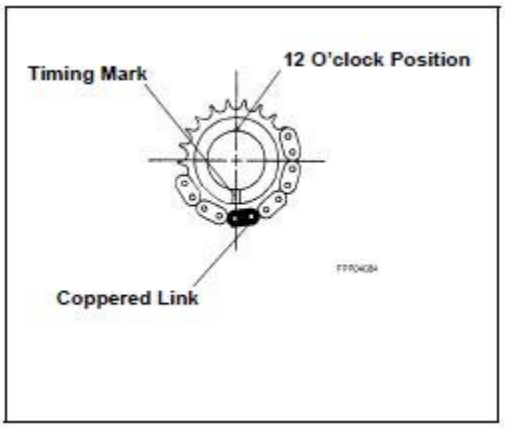


16. Install the chain guide and the tensioner arm from the top of the engine. Install bolts finger tight.

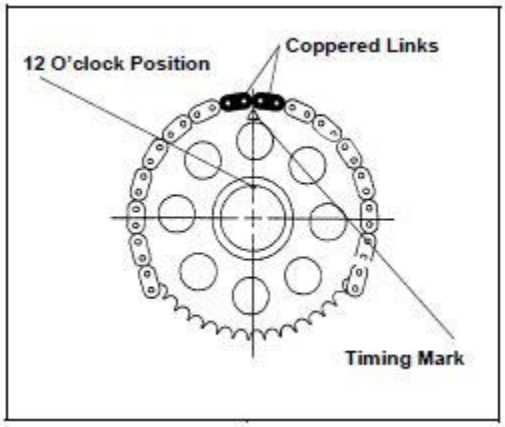


17. Install crankshaft sprocket with key at 12 o'clock position.

18. Assemble drive chain through chain housing cavity from top of engine and onto crankshaft sprocket. Align timing mark with coppered link on drive chain.

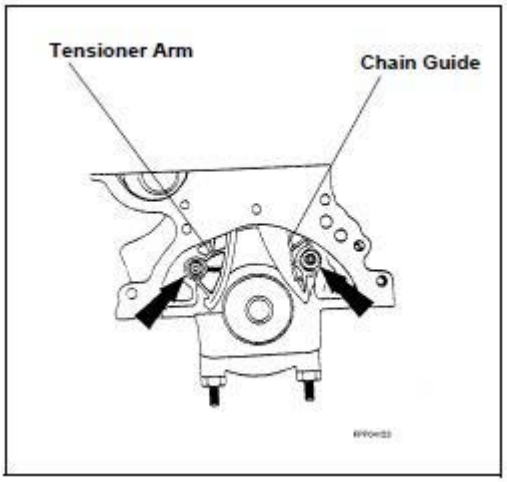


19. Insert camshaft sprocket into chain and assemble to camshaft. Position camshaft key at 12 o'clock and align timing mark between 2 coppered links on drive chain.

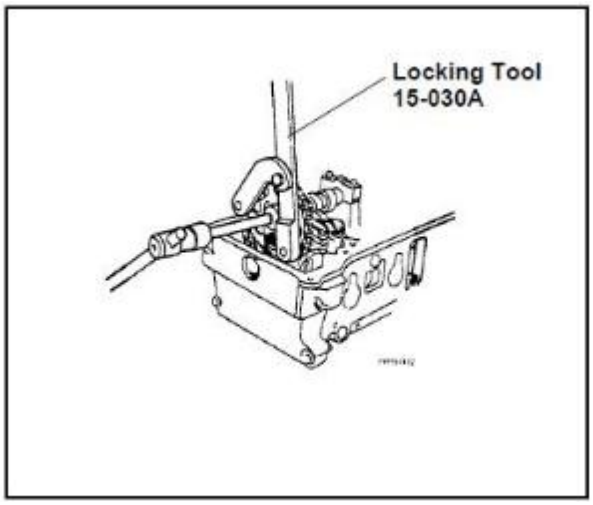


20. Install camshaft sprocket bolt and hydraulic tensioner finger tight.

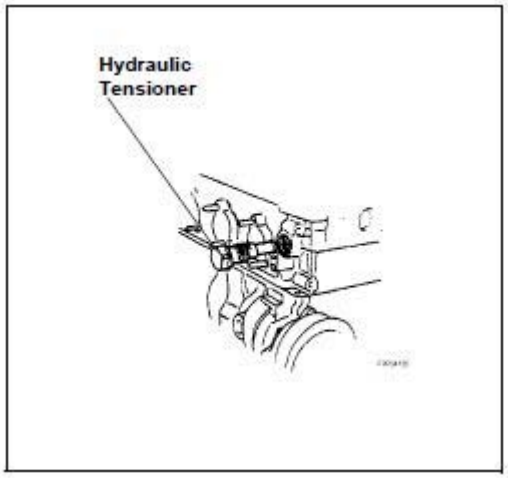
21. Tighten guide and tensioner arm bolts to 18-21 lb.ft. (24-28 Nm).



22. Using locking tool, tighten camshaft sprocket bolt to 59 lb.ft. (70-80 Nm).

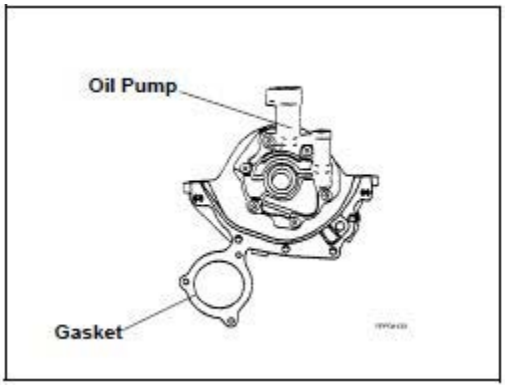


23. Tighten hydraulic tensioner to 27-32 lb.ft. (36-44 Nm).



CAUTION: The oil pump, pulley and sealer are provided as an assembly kept together by a clip (no. BF9A-6606-AA). Do not remove clip until oil pump is installed. If pulley is pushed out of the oil pump prior to oil pump installation.

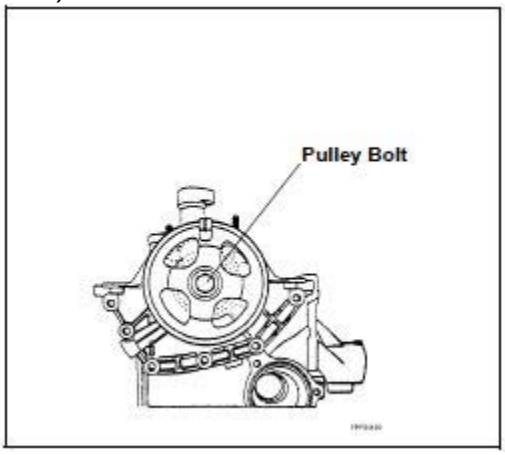
24. Assemble gasket onto oil pump housing guiding it with 2 outer bolts.



CAUTION: Do not apply oil to shaft or seal. Sealing lip along with all contact surfaces must be free of oil.

25. Place oil pump and gasket onto crankshaft.

26. Install pulley bolt and tighten to 92 lb.ft. (125 Nm).

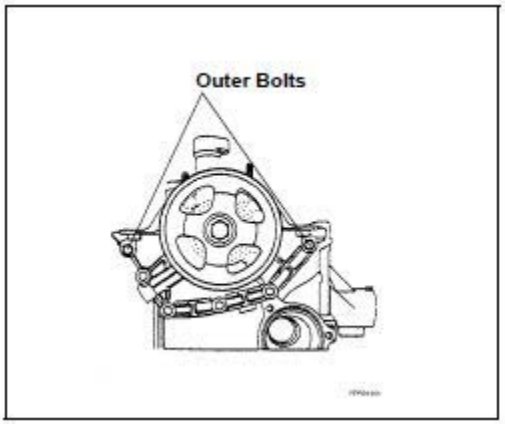


27. Remove clip.

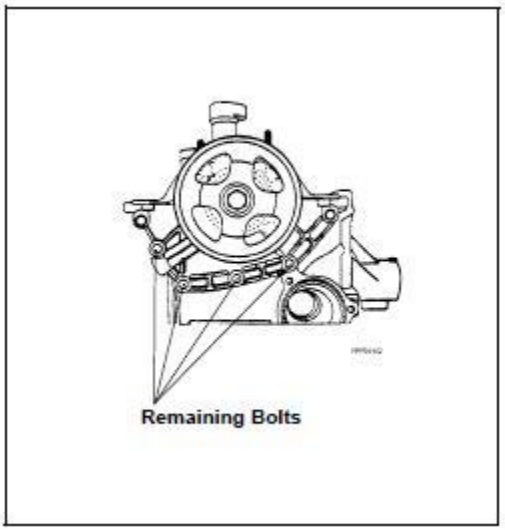
28. Install oil pump housing bolts finger tight.

CAUTION: The oil pump housing must be positioned during tightening of the oil pump housing bolts, so that the sealing flange of the oil pump housing is within ± 0.008 in. (0.20 mm) of the block bottom sealing flanges.

29. Tighten 2 outer oil pump housing bolts to 15 lb.ft. (20 Nm).

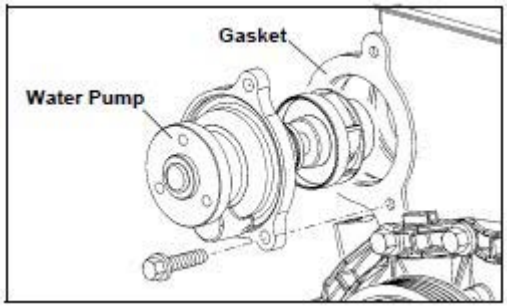


30. Tighten remaining oil pump housing bolts to 15 lb.ft. (20 Nm).



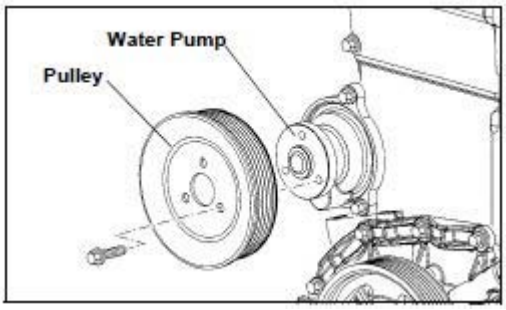
31. Install water pump.

32. Install bolts and tighten to 7 lb.ft. (10 Nm).



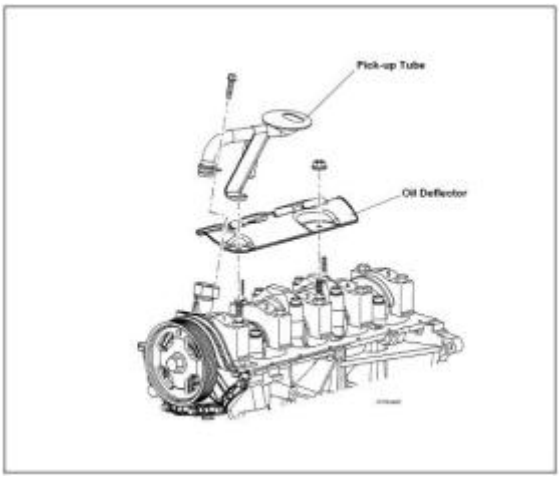
33. Install water pump pulley.

34. Install bolts and tighten to 9 lb.ft. (12 Nm).



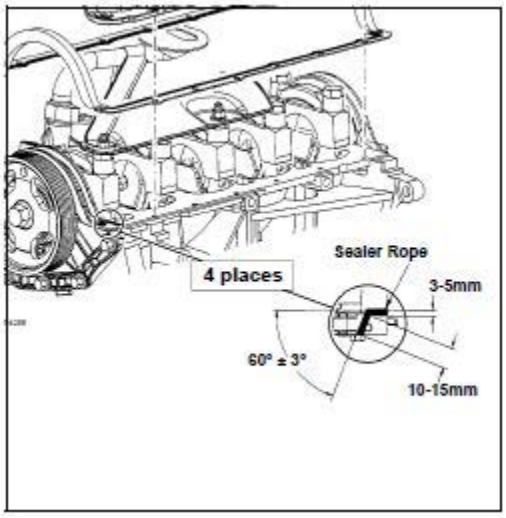
35. Install oil deflector.

36. Install oil pick-up tube.



37. Tighten nuts to 14 lb.ft. (19 Nm). Tighten bolt to 7 lb.ft. (9.5 Nm).

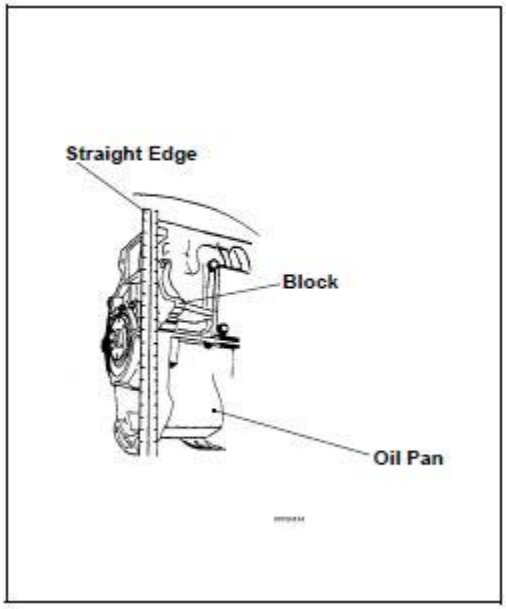
38. Apply WSEM-A4 sealer (Loctite 5910) to the 4 positions as shown.



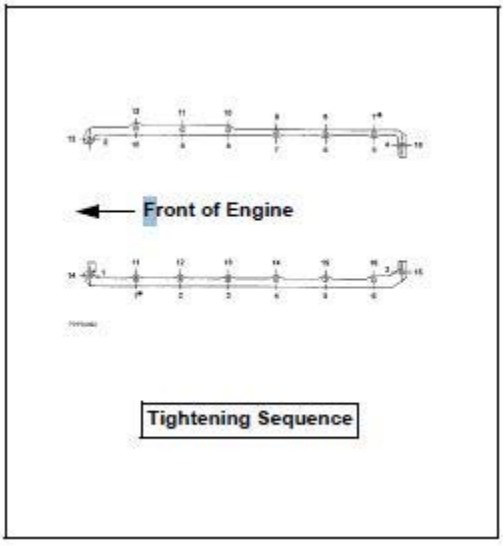
CAUTION: The contact surfaces of oil pan, gasket and block must be free of oil. Do not wait more than 5 minutes to install the oil pan gasket after sealer has been applied.

39. Install the oil pan and bolts finger tight.

40. Align oil pan with rear portion of engine block.

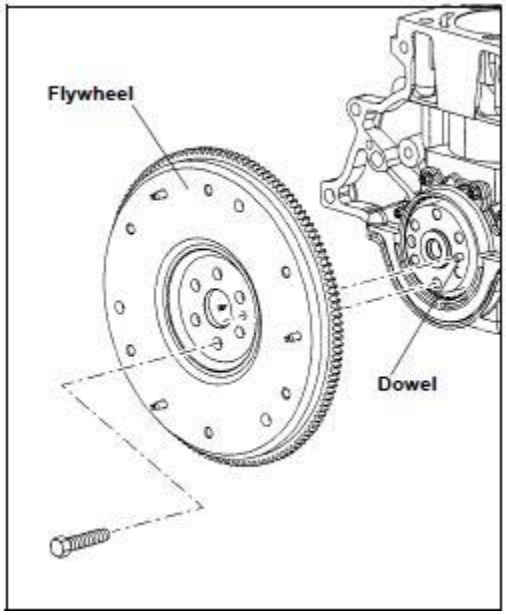


41. Tighten oil pan bolts in 3 steps in the sequence shown:
    - enough for gasket settlement
    - 5 lb.ft. (7 Nm)
    - 7 lb.ft. (10 Nm)



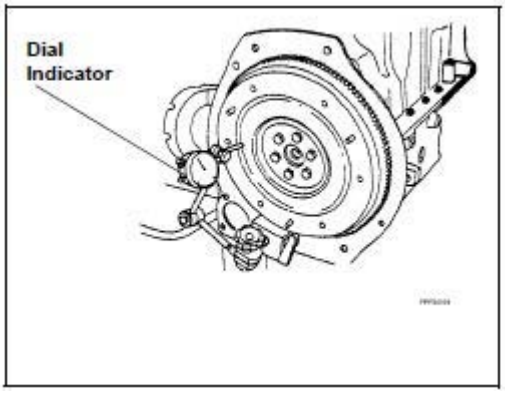
42. Install the oil pan drain plug. Tighten to 18 lb.ft. (25 Nm).

43. Install flywheel using special locking tool 21-168.

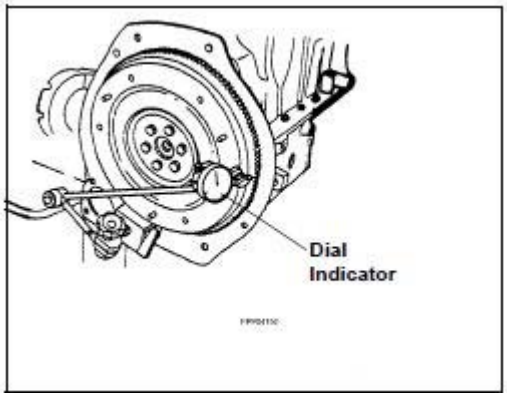


44. Lubricate bolt threads with clean engine oil and tighten to 49 lb.ft. (67 Nm).

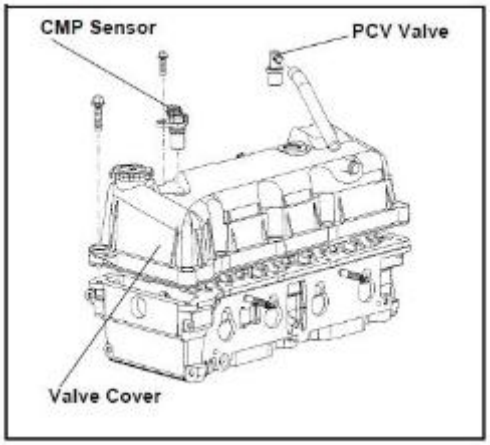
45. Check flywheel runout at clutch disc surface:
    - maximum runout 0.005 in. (0.13 mm)



46. Check flywheel runout at gear surface:
    - maximum runout 0.024 in. (0.6 mm)



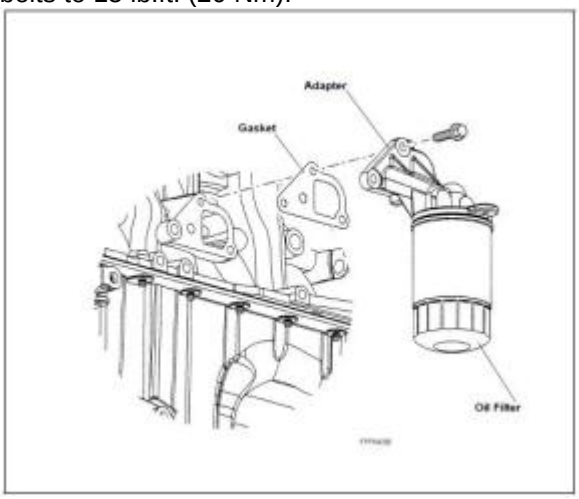
47. Install valve cover and gasket. Tighten bolts to 7 lb.ft. (9 Nm).



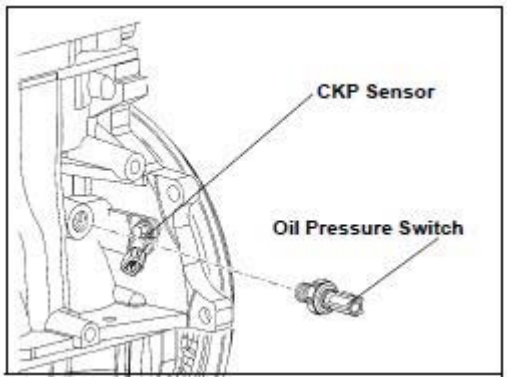
48. Apply grease WSD-M13P8-A1 or equivalent to spark plug threads.

49. Install spark plugs and tighten to 10-13 lb.ft. (13-17 Nm).

50. Install oil filter support with new filter. Tighten bolts to 15 lb.ft. (20 Nm).

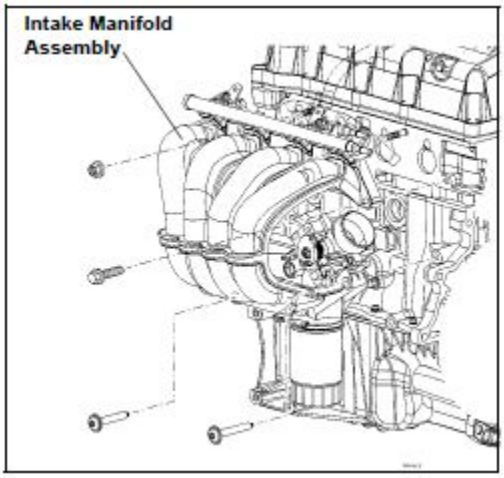


51. Install oil pressure switch and tighten to 15 lb.ft. (20 Nm).

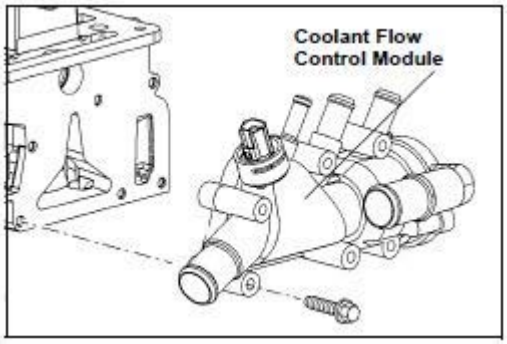


52. Install crankshaft position sensor and tighten to 3 lb.ft. (4 Nm).

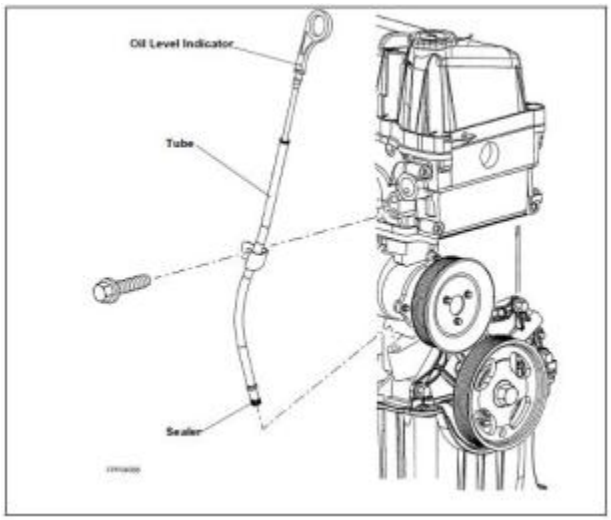
53. Install intake manifold and gasket. Tighten bolts and nuts to 6 lb.ft. (8 Nm).



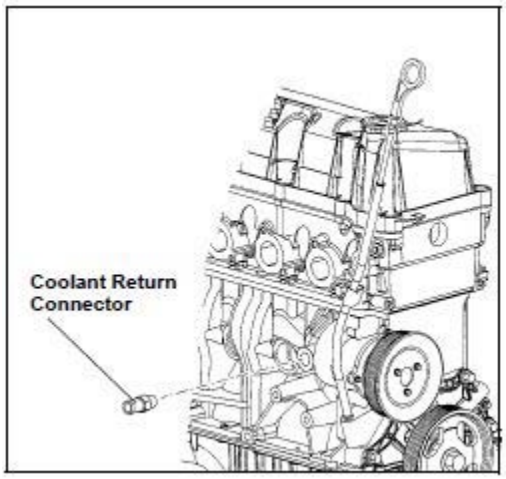
54. Install coolant flow control module and gasket. Tighten bolts to 7 lb.ft. (10 Nm).



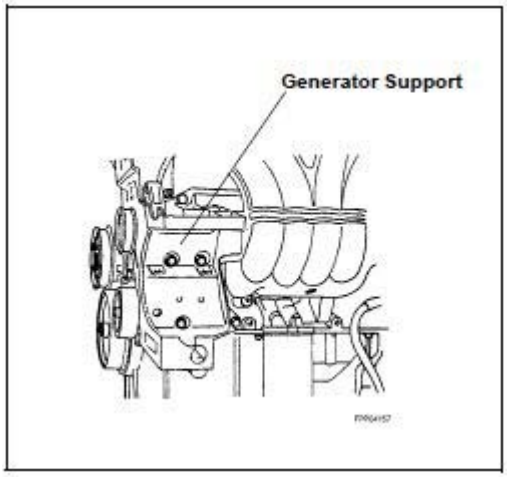
55. Apply sealer WSK-M2G 349-A4 (Loctite 648) to lower end of oil level indicator tube. Install immediately and tighten bolt to 15 lb.ft. (20 Nm).



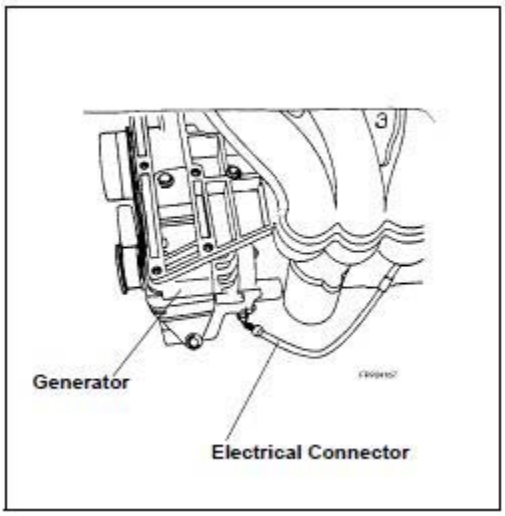
56. Apply sealer WSK-M2G 349-A7 (Loctite 243) to threads of coolant return connector. Install and tighten to 15 lb.ft. (20 Nm).



57. Install generator support



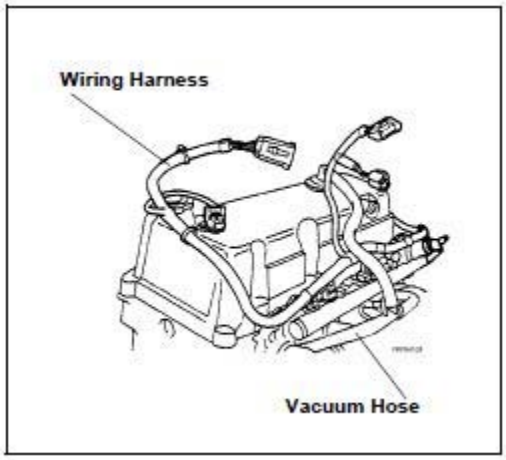
58. Install generator and electrical connectors.



NOTE: Drive belt must be installed in the same direction of rotation as when removed.

59. Pry tensioner pulley as shown and install drive belt.

60. Install engine wiring and vacuum hoses



61. Fill engine with clean engine oil of the correct type and quantity.

NOTE: Ford Power Products industrial engines are designed to perform with engine oils that are licensed by the American Petroleum Institute (API) and oils carrying the most current API classification should be used.

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Engine Type:	4 cylinder, 4 stroke spark ignition 90° Overhead Valve (OHV) chain driven, overhead camshaft operating the valves via roller cam followers.
Liter/CID:	1.6 / 97.5
Bore: mm (in)	82.070 mm (3.23in)
Stroke: mm (in)	75.480 mm (2.97in)
Number of cylinders:	4
Compression ratio:	9.5 : 1

FUEL SYSTEM	
LPG Fuel Type:	Liquefied petroleum gas HD5
NG Fuel Type:	1050 [btu/ft^3]
Gasoline Fuel Type:	Unleaded 87 or 89 Octane, do not exceed 10% ethanol
Fuel Pump Pressure:	40 psi

LUBRICATION SYSTEM	
Max Oil Pressure:	Hot @2500RPM 40 – 60 psi
Oil Type:	SAE 5W30 (API classification SJ)
Service oil fill:	4.2 Liter (4.4quarts) including filter
Oil Filter Type:	X56E-6714-D1A

COOLING SYSTEM	
Thermostat:	Type: Wax Element Commences opening: 180°F Fully Open: 202°F
Coolant:	50% Motorcraft Super Plus 2000 plus 50% clear water

ELECTRICAL SYSTEM	
Polarity:	Negative to earth (ground)

IGNITION	
Spark Plug:	Ford Part #: XS6F-12405-A1A (NGK TR6B-10) Gap: 0.95 – 1.05 mm
Firing Order:	1 – 3 – 4 - 2

CRANKSHAFT	
Main journal-standard diameter:	2.243 - 2.244 in (56.980 – 57.000 mm)
Main journal-undersize diameter:	2.233 – 2.234 in (56.726 – 56.746 mm)

ITEM	Nm	FT. LB.	LB. IN.
Oil Pan Drain Plug	25	18	221.3
Spark Plugs	13 – 17	9.6 – 12.5	115 – 150.5
Oil Filter	11 – 15	8 – 11	97.4 – 132.7

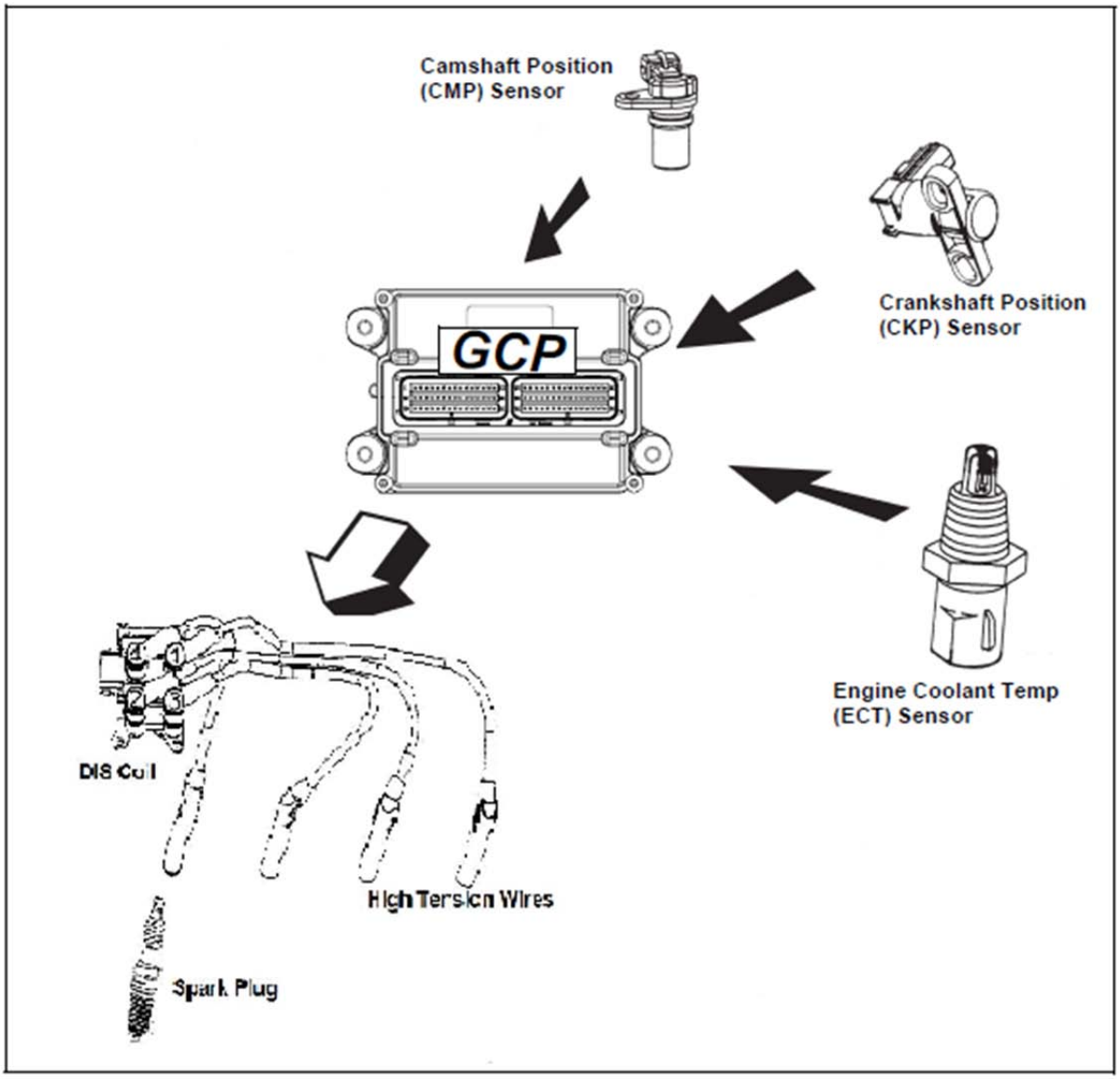
TSG-416 IGNITION SYSTEM

INDEX

Subject	**Page**
General Information	**03 - 2**
Description	03 – 3
Operation	03 – 3
Wiring Diagram	03 – 4
Diagnosis and Testing	
Spark Plug Inspection	03 – 5
Removal and Installation	
Ignition Coil – Replacement	03 – 6
Spark Plug – Removal	03 – 6
Spark Plug – Installation	03 – 6
Specifications	**03 – 7**

TSG-416 IGNITION SYSTEM

GENERAL INFORMATION



Description

The TSG-416 engine is equipped with an coil pack electronic ignition system. The brain of this system is the Electronic Engine Control (GCP) Module which receives inputs from the following:

- Crankshaft Position (CKP) Sensor
- Camshaft Position (CMP) Sensor
- Engine Temperature Sensor

From these inputs, the GCP module computes spark strategy (spark advance) to obtain optimum engine performance for correct input conditions, through the following outputs

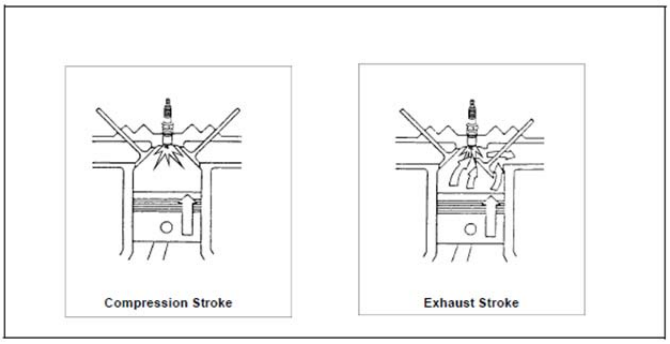
- Ignition Coil pack
- Spark Plugs.

WARNING: HIGH TENSION VOLTAGE PRODUCED BY A DISTRIBUTORLESS IGNITION SYSTEM IS HIGHER THAN FOR A CONVENTIONAL IGNITION SYSTEM. WHEN CARRYING OUT SERVICE OPERATIONS ON AN ENGINE EQUIPPED WITH DISTRIBUTORLESS IGNITION, IT IS IMPORTANT TO BE AWARE OF THE ABOVE POINT AS WELL AS ALL THE USUAL SAFETY MEASURES TO PREVENT THE POSSIBILITY OF ELECTRIC SHOCKS.

Operation

With this system, the GCP monitors the engine speed and operating temperature and decides what degree of spark advance is correct for all of the operating conditions. Because timing is set for life inherently in the design of the engine, and there are no moving parts in the ignition system itself, no maintenance is required except for periodic spark plug checks. The system provides for fixed spark advance at start-up, for cold weather starting, and for “average value” default attention has been given to spark optimization for excellent fuel economy in the warm-up mode.

The spark plugs are paired so that one plug fires during the compression stroke and its companion plug fires during the exhaust stroke. The next time that coil is fired, the plug that was on exhaust will be on compression, and the one that was on compression will be on exhaust. The



spark in the exhaust cylinder is wasted (referred to as the “waste spark”) but little of the coil energy is lost.

Engine Speed and Crankshaft Position

The crankshaft position and speed information comes to the GCP from the Crankshaft Position (CKP) Sensor, mounted near the crankshaft pulley. The CKP Sensor is triggered by teeth on a trigger wheel located on the crankshaft pulley. The pulse frequency indicates crankshaft speed and a missing tooth indicates crankshaft position.

Engine Temperature

The Engine Coolant Temperature (ECT) Sensor sends engine temperature information to the GCP. It is located in the rear coolant outlet pipe.

Fuel Octane Level Adjustment

In the event that the engine is operated on dry fuels such as natural gas, compressed natural gas (CNG), or liquefied petroleum gas (LGP), timing can be modified by GCP “Fuel Type”.

Ignition Coil Driver

The GCP switches 2 individual ignition coils on and off at the correct times to give the desired spark advance. Ignition timing is adjusted constantly by the GCP. Many factors including all the sensor inputs, affect the final ignition setting.

Run Mode

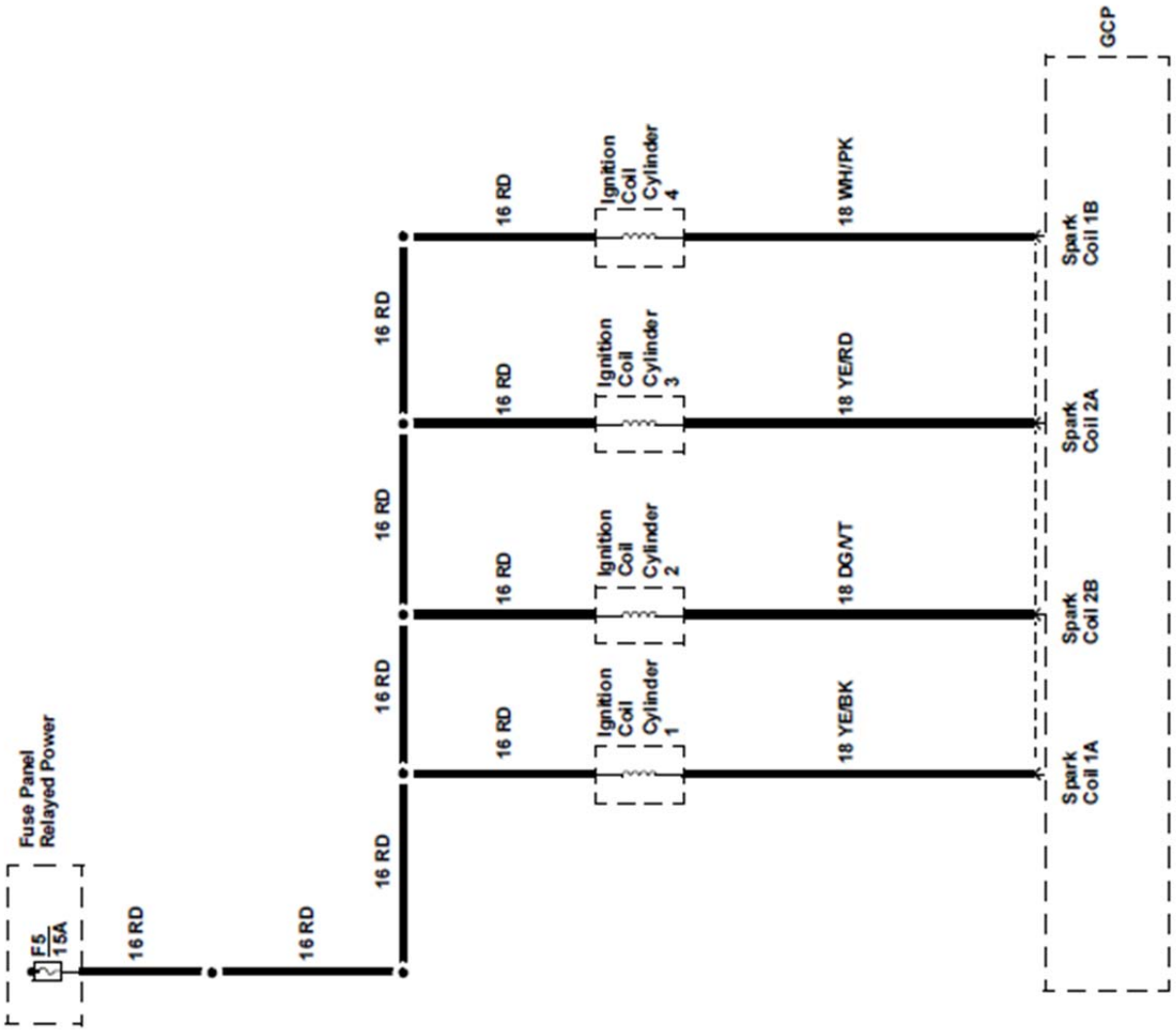
The GCP interprets engine speed above 200 rpm as Run Mode. The Base Spark advance (BSA) is calculated by the GCP processing the engine speed input.

Transient Mode

This function is to provide detonation protection when the engine load is increased rapidly by fast opening of the throttle plate.

TSG-416 IGNITION SYSTEM

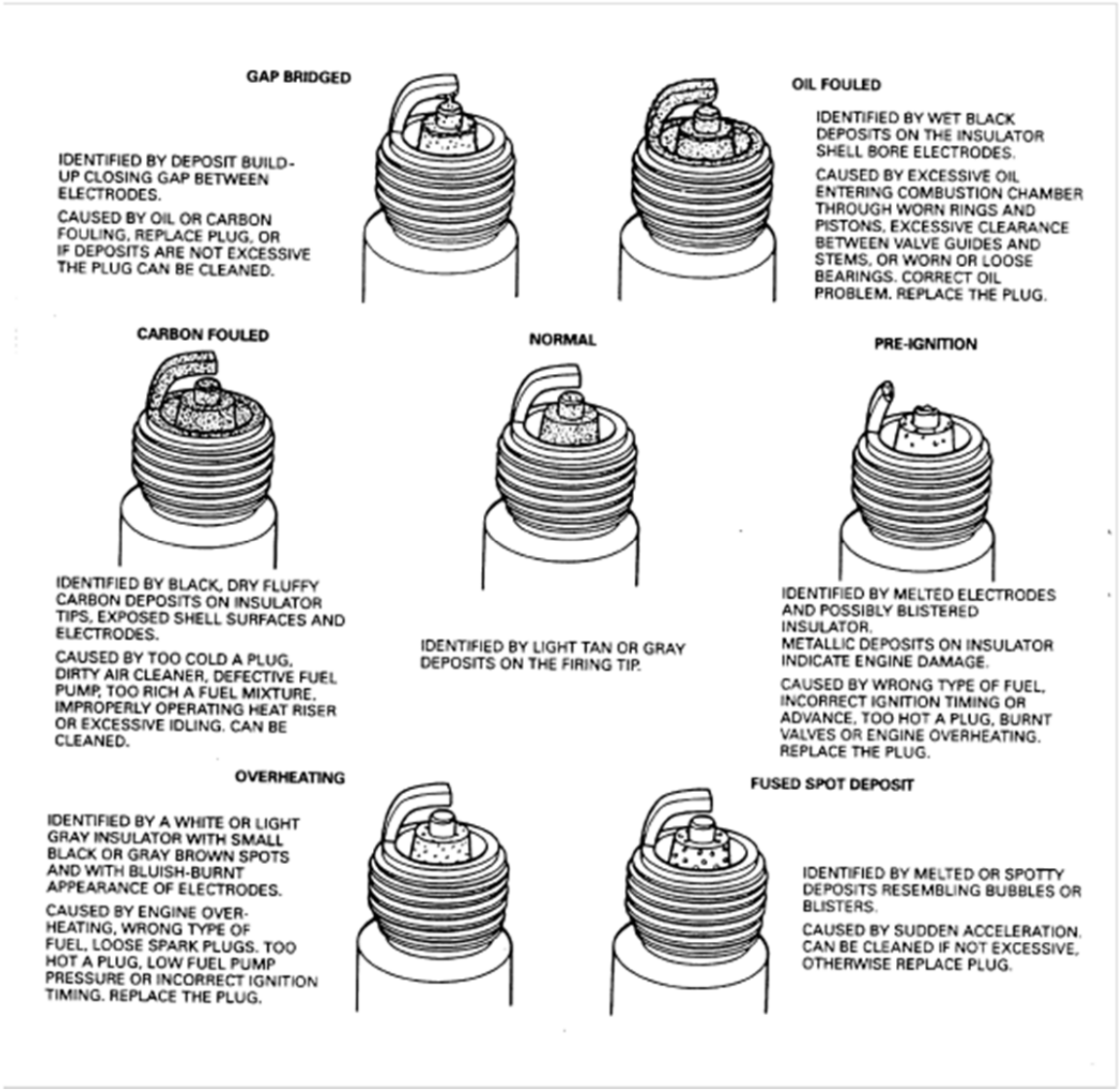
Wiring Diagram



DIAGNOSIS AND TESTING

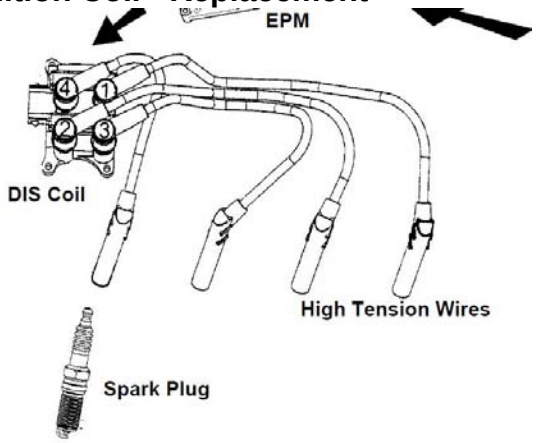
Spark Plug Inspection

Inspect the spark plug tip as in the chart below:



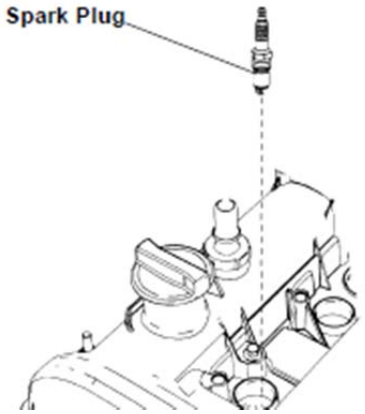
REMOVAL AND INSTALLATION

Ignition Coil - Replacement



1. Remove and/or disconnect components to allow access and removal of the ignition coil pack. Label if necessary to allow for correct reinstallation.
2. Disconnect electrical connector from the engine harness then disconnect the high tension wires that go to each spark plug.
3. Remove four bolts.
4. Remove the ignition coil pack.
5. Reverse procedure to install:
    - Inspect for cracks, carbon tracking or dirt
    - Apply silicone dielectric compound to the inside of coil.

Spark Plug – Removal



1. Remove ignition coil -- Refer to “Ignition Coil - Replacement” on page 6 of this section.
2. Loosen spark plugs and remove any dirt or foreign material from spark plug areas of cylinder head with compressed air.
3. Remove spark plugs and mark location using a piece of masking tape.
4. Inspect condition of spark plug -- Refer to “Spark Plug Inspection” on page 7 of this section.

Spark Plug - Installation

1. Apply a few drops of engine oil to spark plug threads near tip.
2. Adjust spark plug gap to: 1.06 - 1.16 mm (0.042 - 0.046 in.).
3. Install spark plugs (to original locations) and tighten to 11 lb-ft. (15 Nm).
4. Install coil -- Refer to “Ignition Coil - Replacement” on page 6 of this section.

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Firing Order	1 – 3 – 4 - 2
Spark Plug	Type: 5G5E-12405-AA Gap: 1.06 – 1.16 mm (0.042 – 0.046 in.)

TORQUE SPECIFICATIONS			
Description	Nm	Lb-ft	Lb-in
Spark Plugs	15	11	132
Coil bolts	8	6	71

TSG-416 FUEL SYSTEM

INDEX

Subject	Page
Cautions & Warnings	**04 – 2**
General Information – Gasoline	**04 – 3**
Description	04 – 3
Operation	04 – 4
Fuel System Requirements	04 – 4
Wiring Diagram	04 – 5
General Information – Dry Fuel	**04 – 7**
Description	04 – 7
Operation	04 – 7
Fuel System Requirements	04 – 8
Wiring Diagram	04 – 9
Diagnosis and Testing – LPG	04 – 10
Symptom Chart	04 – 10
Preliminary Tests	04 – 11
Diagnostic Charts	04 – 12
Diagnosis and Testing – GASOLINE	04 – 21
Visual Inspection	04 – 21
Symptom Chart	04 – 21
Fuel Pressure Check	04 – 21
Fuel Pump Check	04 – 21
Fuel Block Check	04 – 22
General Service Procedures	04 – 23
Spring Lock Coupling – Type I – Disconnect	04 – 23
Spring Lock Coupling – Type I – Connect	04 – 23
Spring Lock Coupling – Type II – Disconnect	04 – 23
Spring Lock Coupling – Type II – Connect	04 – 23
Quick Connect Coupling – Type I – Disconnect	04 – 23
Quick Connect Coupling – Type I – Connect	04 – 23
Quick Connect Coupling – Type II – Disconnect	04 – 23
Quick Connect Coupling – Type II – Connect	04 – 24
Removal and Installation	
Fuel Rail & Injectors – Replacement	04 – 25
Actuator – Removal	04 – 26
Actuator – Installation	04 – 26
Mixer – Removal	04 – 26
Mixer – Installation	04 – 27
Specifications	**04 – 27**

CAUTIONS & WARNINGS

WARNING: DO NOT SMOKE OR CARRY LIGHTED TOBACCO OR OPEN FLAME OF ANY TYPE WHEN WORKING ON OR NEAR ANY FUEL-RELATED COMPONENT. HIGHLY FLAMMABLE MIXTURES ARE
ALWAYS PRESENT AND MAY BE IGNITED. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

WARNING: FUEL IN THE FUEL SYSTEM REMAINS UNDER HIGH PRESSURE EVEN WHEN THE ENGINE IS NOT RUNNING. BEFORE REPAIRING OR DISCONNECTING ANY OF THE FUEL LINES OR FUEL SYSTEM COMPONENTS, THE FUEL SYSTEM PRESSURE MUST BE RELIEVED TO PREVENT ACCIDENTAL SPRAYING OF FUEL, CAUSING A FIRE HAZARD. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

WARNING: DO NOT CARRY PERSONAL ELECTRONIC DEVICES SUCH AS CELL PHONES, PAGERS OR AUDIO EQUIPMENT OF ANY TYPE WHEN WORKING ON OR NEAR ANY FUEL-RELATED COMPONENTS. HIGHLY FLAMMABLE MIXTURES ARE ALWAYS PRESENT AND CAN BE IGNITED. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

WARNING: THESE PROCEDURES INVOLVE FUEL HANDLING. BE PREPARED FOR FUEL SPILLAGE AT ALL TIMES AND ALWAYS OBSERVE FUEL HANDLING PRECAUTIONS. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

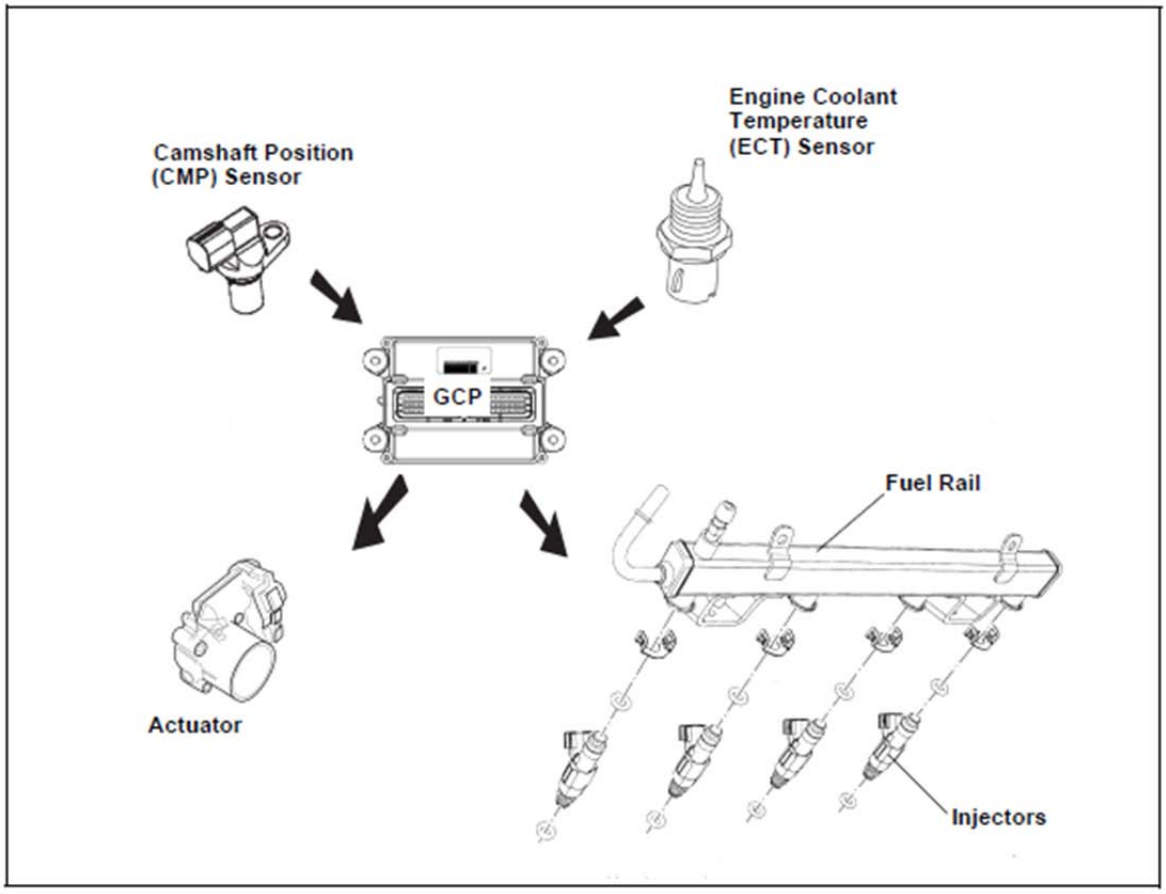
CAUTION: If the liquid or vapor tube is damaged (torn, holes or delaminated), a new tube assembly must be installed. Do not use aftermarket sleeving. Do not re-adhere loose sleeving material.

CAUTION: Fuel injection equipment is manufactured to very precise tolerances and fine clearances. It is therefore essential that absolute cleanliness is observed when working with these components. Always cap off any open orifices or tubes.

CAUTION: When reusing liquid or vapor tube connectors, make sure to use compressed air to remove any foreign material from the connector retaining clip area before separating from the tube. Apply clean engine oil to the end of the tube before inserting the tube into the connector.

CAUTION: To ensure absolute cleanliness is observed when working with fuel system components, always cap off any open orifices or tubes.

GENERAL INFORMATION - GASOLINE



Description

The fuel system delivers fuel by an electronic fuel pump. A fuel pressure regulator controls fuel pressure and also contains a fuel filter. The Electronic Control Module (GCP) uses information from various sensors and controls fuel delivery to the cylinders by individual fuel injectors mounted in the cylinder head near each intake valve. Air delivery is controlled by an actuator.

Fuel Rail

The fuel rail is mounted to the top of the engine and distributes fuel to the individual injectors. Fuel is delivered to the fuel inlet tube of the fuel rail by the fuel lines and hoses.

Fuel Injector

The fuel injector is a solenoid operated device mounted to the cylinder head. The GCP energizes the solenoid, which opens a valve to allow fuel delivery into the cylinder.

Camshaft Position (CMP) Sensor

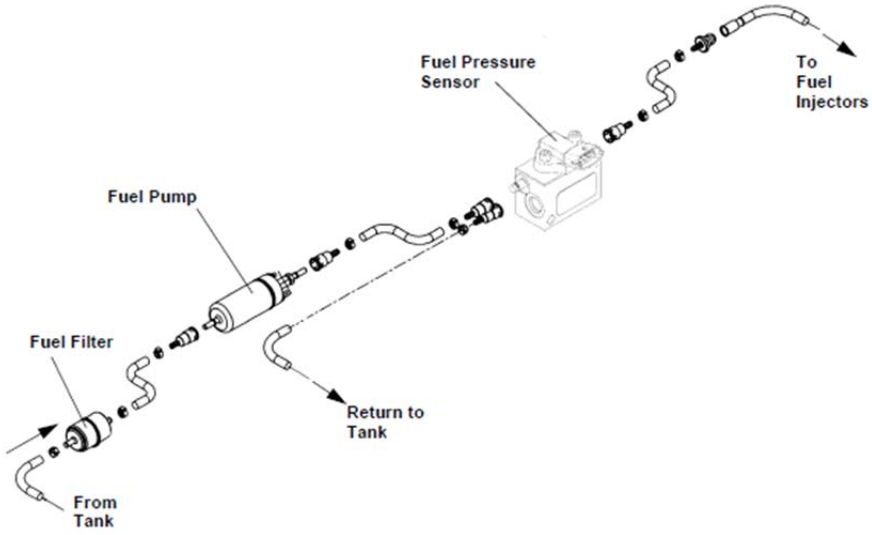
The Camshaft Position (CMP) Sensor is mounted in the camshaft cover. This signal is sent to the GCP which uses it to indicate the position of the #1 piston during its power stroke. The GCP uses the CMP signal as a “sync pulse” to trigger the injectors in the proper sequence. This allows the GCP to calculate true sequential fuel injection (SFI) mode of operation.

Engine Coolant Temperature (ECT) Sensor

The Engine Coolant Temperature (ECT) Sensor is a thermistor mounted in the engine coolant stream in the rear coolant outlet pipe. The GCP uses this information to calculate the correct air/fuel mixture which varies with engine temperature.

Actuator

The actuator controls air delivery into the cylinders. An integral Throttle Position (TP) Sensor sends a signal to the GCP indicating throttle position. The GCP calculates fuel delivery based on throttle valve angle (operator demand).



Operation

The fuel delivery system starts with the fuel in the tank. Fuel is drawn up to the fuel pump through a pre-filter. The electric fuel pump then delivers the fuel to the fuel rail and injectors. The GCP controls the fuel pump to deliver fuel pressure required by the injectors. The GCP monitors system pressure through a fuel pressure sensor.

Fuel is injected under pressure in a conical spray pattern at the opening of the intake valve. There is a return line to the tank with a small orifice to prevent vapor lock in the pump

An actuator controls air supply to the intake manifold. Governor settings are not adjustable. They can only be programmed by authorized personnel only. Contact your local EDI Distributor listed in the back of this manual for further information.

CAUTION: Do not force the throttle plate open. This may cause permanent damage to the actuator.

A pressure relief valve is located on the fuel rail. This is used to read fuel pressure and also to relieve fuel pressure prior to component replacement.

The GCP controls the amount of fuel/air delivery – refer to the Electronic Engine Control section for further information.

Fuel System Requirements

Fuel Tanks

The DOEM or OEM supplies the tanks. There must be a fuel outlet and a fuel inlet. The gas cap must also be vented per the emission installation instructions.

Wet Fuels

The following fuels must all be unleaded and clean:

- Gasoline/petrol: This engine is designed to operate on unleaded 87 or 89 octane gasolines.
- Gasohol/Ethanol: A mixture of gasoline and ethanol (grain alcohol) containing up to 10% ethanol by volume with properly formulated cosolvents and other necessary additives. Blends index of 87 or 89.
- Gasohol/Methanol: A mixture of gasoline and alcohol (wood alcohol, etc.) containing up to 5% methanol by volume with properly formulated cosolvents and other necessary additives. Blends index of 87 or 89.

Fuel Pump

The fuel pump must be mounted on the frame rail, not on the engine. It must also be mounted in packed foam.

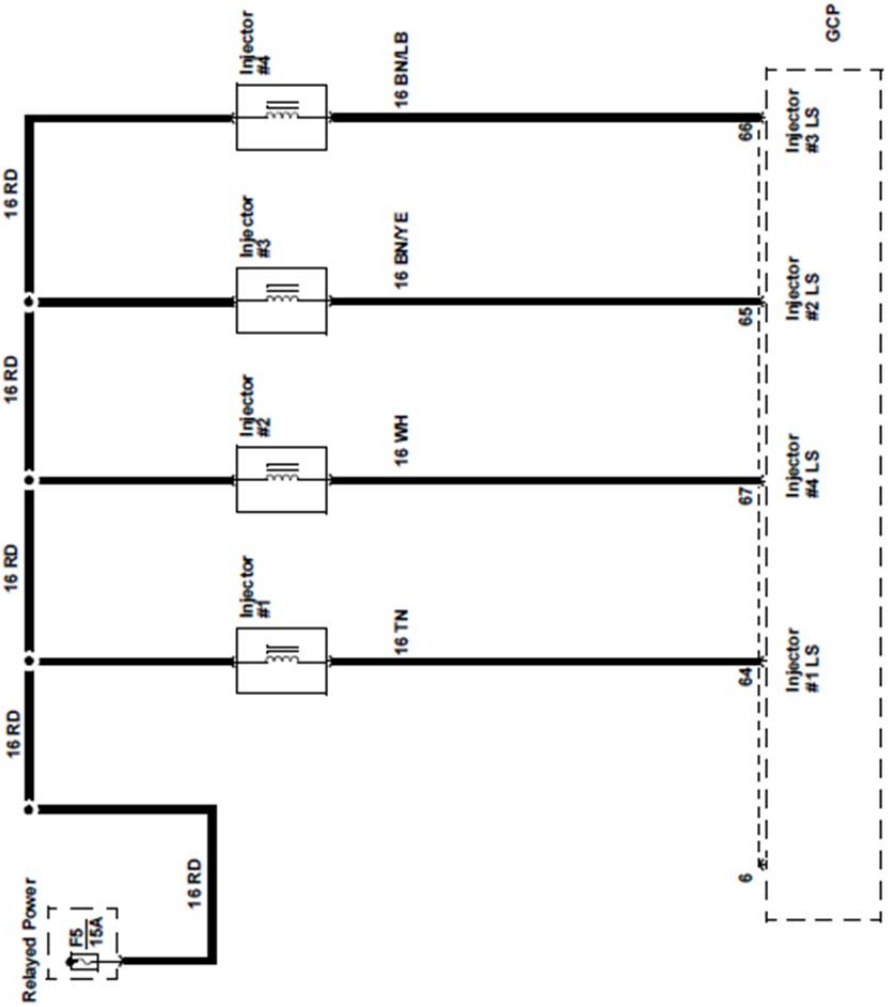
CAUTION: The electric fuel pump MUST NOT be mounted directly on the engine assembly, as engine vibration will shorten the life of the pump.

Wiring Diagrams

Revision Level
The following wiring schematics are taken from the wiring diagram listed below.

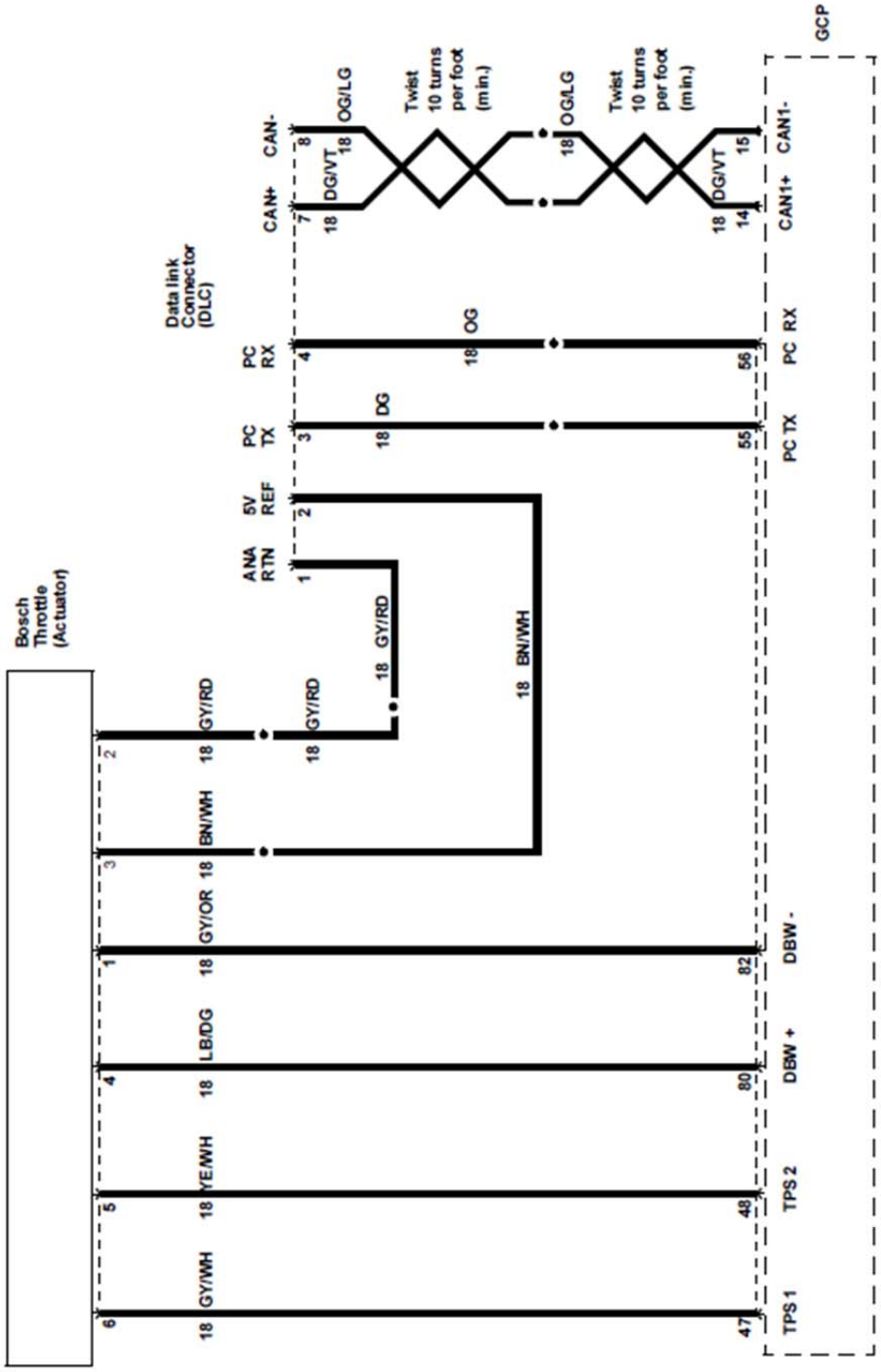
Title: EDI / FORD 1.6L W/GCP 2010 DEPR		
Size: D	Number: 2122200	Rev: B
Date: 7/1/2010	Drawn By: J. SUTTON	
Filename: 2122200b.sch	Sheet 1 of 1	

Fuel Injectors



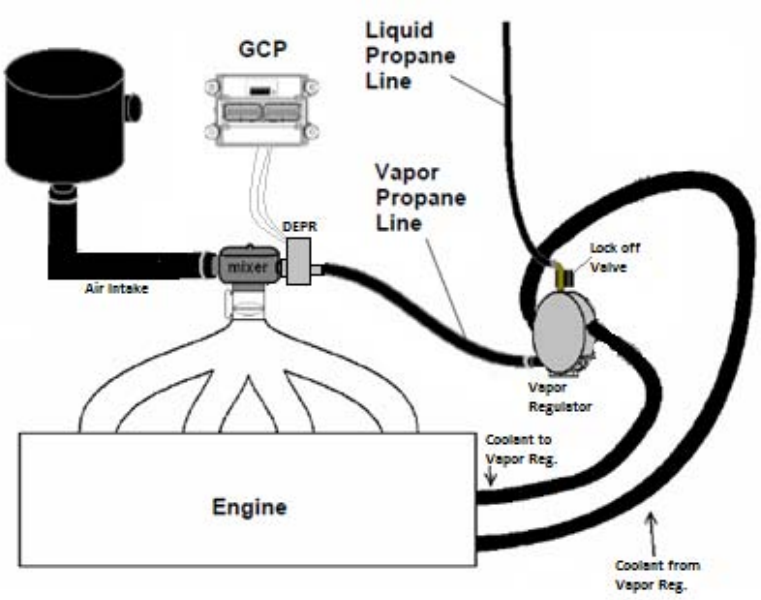
Actuator / Data Link

Connector (DLC)



TSG-416 FUEL SYSTEM

GENERAL INFORMATION –

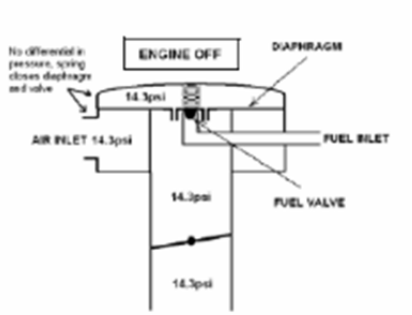


DRY FUEL

Description

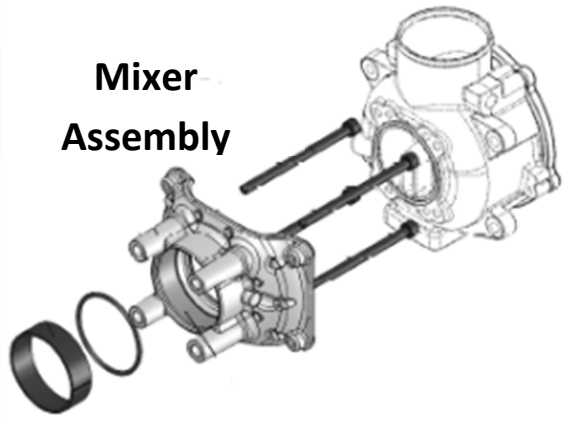
This engine with the proper fuel equipment can also operate on dry fuel such as LPG Grade HD5 and natural gas (1050 BTU/ft3). Natural Gas fuel specification must meet or exceed 38.7 MJ/m3 (UK) 39.0 MJ/m3 (USA). Vaporized propane is introduced into the engine with a

Vapor Carburetor. Pressure is regulated by an Direct Electronic Pressure Regulator (DEPR) which is controlled by the GCP. Coolant is circulated through the DEPR.



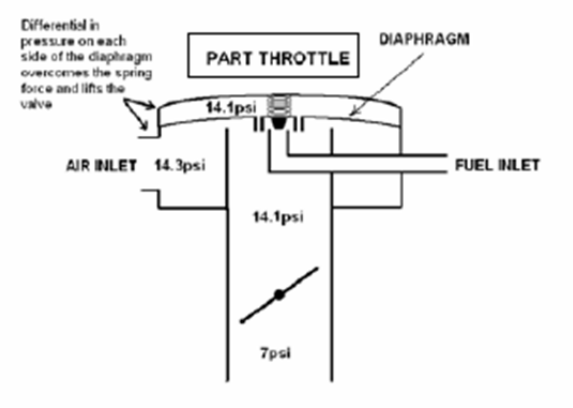
Operation

The dry fuel vapor carburetor is a device by which fuel can be added to passing air flow. The amount of fuel added is related to the amount of air passing through the carburetor.

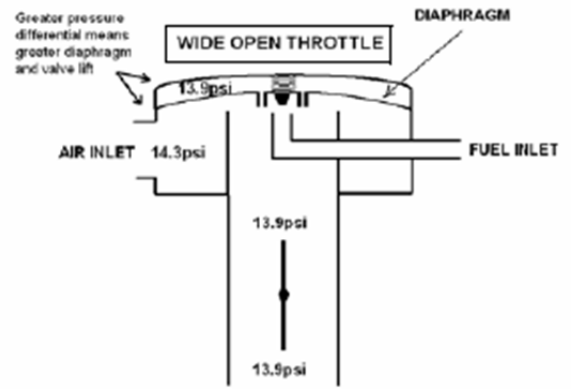


The variable venturi carburetor controls fuel flow based on a differential pressure across the diaphragm. The more air the engine demands, the lower the pressure in the throat and hence on the top of the diaphragm. When the pressure on the top of the diaphragm is low enough, the diaphragm overcomes the spring force holding it down and lifts and allows fuel to be drawn from the fuel port into the air flow into the engine.

TSG-416 FUEL SYSTEM

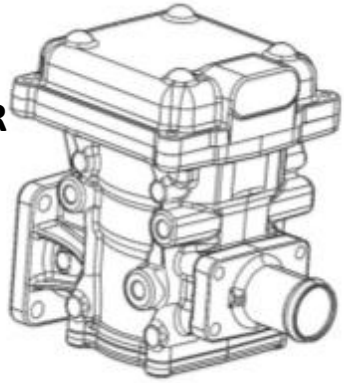


The greater the airflow into the engine, the greater the pressure drop across the diaphragm and the more lift occurs on the fuel valve. This allows more fuel to be drawn into the engine.

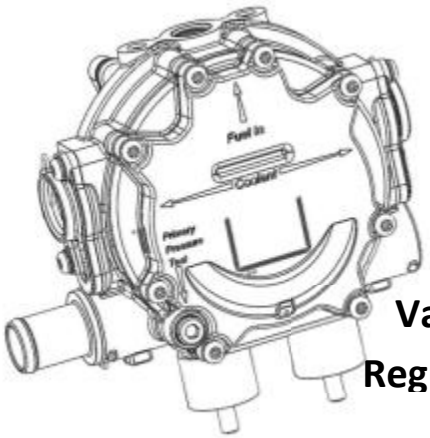


While the carburetor is designed to mix the fuel and air and adjust fuel to match the speed and load of the engine, it has only “ballpark” accuracy. This accuracy is not fine enough to achieve emissions targets. To achieve accurate fueling, the air inlet pressure to the carburetor is controlled by a Direct Electronic Pressure Regulator (DEPR).

DEPR



The DEPR serves to control the vapor pressure to the mixer. After the propane is vaporized (vapor regulator), the DEPR monitors and controls the vapor pressure to the mixer in reference to the inlet air pressure to the carburetor (mixer).



Vapor Regulator

The DEPR receives a pressure command from the GCP called “Delta P” which is the difference between fuel vapor pressure and the air inlet pressure. This has been calibrated for all speeds and loads. There is a sensor internal to the DEPR that measures the actual “Delta P” of the delivered fuel.

The actuator of the DEPR will then adjust the fuel pressure to the carburetor so that the actual “Delta P” matches the Delta P command from the GCP.

This provides an extremely accurate open loop type of fuel control. After a preset time has passed, the engine will go into closed loop control, using information from the pre and post oxygen sensors to allow further adjustment to meet emissions regulations.

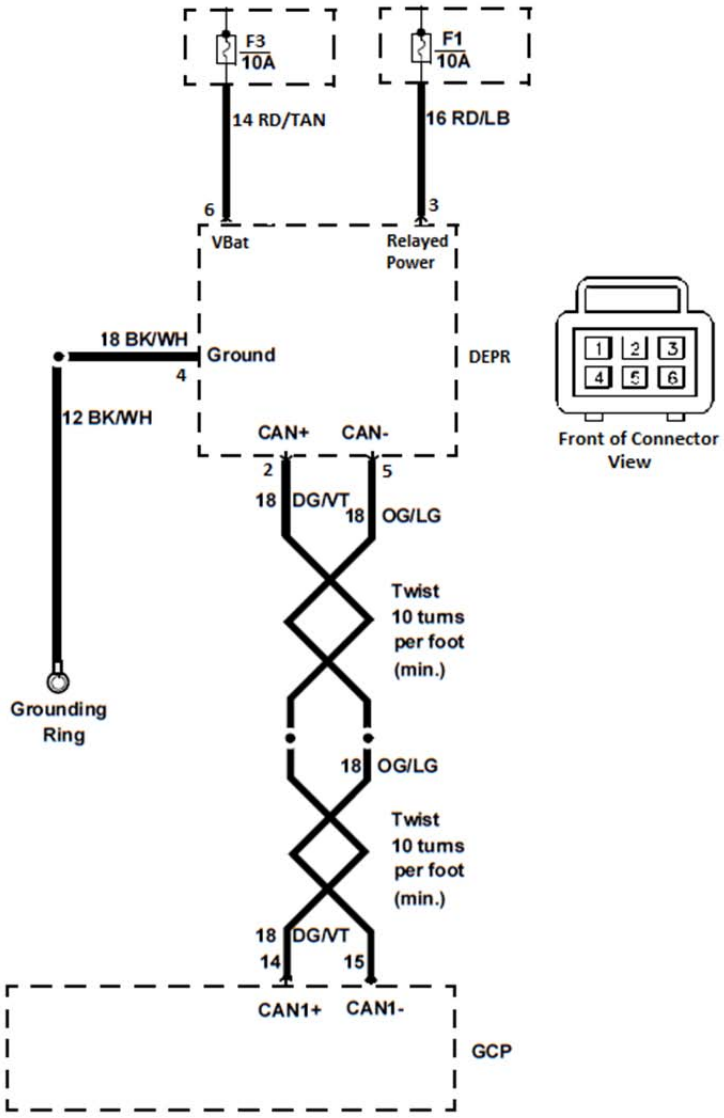
Wiring Diagrams

Revision Level

The following wiring schematics are taken from the wiring diagram labeled below.

Title: EDI / FORD 1.6L W/GCP 2010 DEPR		
Size: D	Number: 2122200	Rev: B
Date: 7/1/2010	Drawn By: J. SUTTON	
Filename: 2122200b.sch	Sheet 1 of 1	

Engine Controls – Dry Fuel DEPR



DIAGNOSIS AND TESTING - LPG

Symptom Chart

Symptom	Go to
Engine cranking but will not start	Page 12
Engine starts but has rough idle	Page 14
Engine idles with rough acceleration at load	Page 14
Engine is unable to reach full power	Page 14
Overall power loss	Page 12
Engines misses	Page 14
Backfire	Page 16
Emissions failure (Rich Mixture)	Page 17
Emissions failure (Lean Mixture)	Page 18
Engine overheats	Page 19
Engine stops running (Dies)	Page 20

Preliminary Test

This pinpoint test checklist is your guide to the most probably causes of an engine performance complaint when the malfunction is due to the fuel system.

Test Step		Result	Action to Take
1	Inspect Installation.		
• Check fuel hose for kinks • Check fuel hose lengths, orientation and presence of parts **Is Everything OK?**		**Yes** **No**	Go to Step 2.. Repair as necessary
2	Inspect Fuel system for supply leaks.		
• Key OFF • Check for leaks or damaged supply lines from the fuel tank to the fuel lock off valve **Are there any leaks present?**		**Yes** **No**	Repair the leak Go to Step 3…
3	Inspect the Fuel system for any loose wires or hoses.		
• Key OFF • Check the fuel lockoff connection and fuel check valve connection • Check the vacuum hoses for any damage or leakage **Is there any damaged or loose wires and hoses?**		**Yes** **No**	Repair or replace as necessary Go to step 4
4	Check for fuel system leaks		
• Key ON • Check the fuel system for leaks • Key OFF **Are there any leaks present?**		**Yes** **No**	Repair the leak Go to step 5.
5	Check carburetor air inlet for obstructions		
• Remove the air cleaner **Are there any obstructions in the air inlet of the carburetor?**		**Yes** **No**	Remove the obstruction, re-install the air cleaner and attempt to start Proceed to appropriate troubleshooting section

Diagnostic Charts

Perform the preliminary test before proceeding.

Engine Cranking but Will Not Start

Test Step		Result	Action to Take
1	Check fuel tank	**Yes**	Fill or replace the fuel tank. (Do not exceed 80% of liquid capacity)
Is fuel tank empty?		**No**	Go to Step 2.
2	Check fuel valve	**Yes**	Slowly open the fuel valve
Is liquid fuel valve closed?		**No**	Go to step 3.
3	Check the excess flow valve	**Yes**	Reset excess flow safety valve • Close the main fuel valve • Wait for a clicking sound from the excess flow valve indicating the valve has reset • Slowly open the main fuel valve
Is excess fuel valve tripped and closed?		**No**	Perform prelim. Test before proceeding to step 4
4	Check lockoff valve supply voltage	**Yes**	12 volts to lockoff activation circuit is open, shorted to gnd or the GCP module is faulty. Check wiring, connectors and fused for possible cause.
• Key OFF • Disconnect lock off valve connector from harness • Key ON • Using a high impedance DVOM, check for 12 volt supply at the harness connector **Is the voltage less than 11.5 volts?**		**No**	Go to step 5.
5	Check primary fuel pressure to regulator	**Yes**	Fuel filter element may be clogged, inspect and/or replace the fuel filter. Lockoff valve may be faulty, replace the lockoff valve.
• Verfiy that 120-180 psi is going to the regulator • Check downstream of the lock off valve • Key ON **Is the pressure not in the above range?**		**No**	Go to Step 6
6	Check for icing or freezing of the regulator.	**Yes**	The presence of ice on the converter without the engine cranking indicated the possibility of a fuel leak past the primary sea of the converter.
• Key ON • Check for ice or frost build up on the converter casing and outlet port • Key OFF • **Is ice present?**		**No**	May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

Diagnostic Aids

Fuel Lock Solenoid: The fuel lock is an electronic solenoid that is opened to allow fuel flow when the key is turned ON. High temperatures may cause the solenoid to become intermittent, not opening to supply sufficient fuel pressure.

Fuel Filter: There may be a filter element located in the inlet of the fuel lockoff valve which may become clogged and limit fuel flow, especially at low tank pressures. Check the filter and replace or clean as necessary.

Fuel Line Restrictions: The vehicle specifications table specifies the fuel line to be a certain size. If the fuel line from the tank to the fuel lock is not the proper size, or any valves or fittings with flow restrictive characteristics are used, the fuel flow will not be sufficient to the converter with low tank pressure. Correct any fuel line or fitting restrictions.

Mixer Assembly (Carburetor): It is possible that a backfire may have caused the fuel valve to partially come off of its retainer and restrict fuel, check the mixer fuel valves.

Regulator Assembly (Converter): If no other problems have been identified, replace the fuel management assembly with a known good part of the same pressure range. Retest.

The pinpoint tests below should be performed after the preliminary tests and "Engine Cranks but Will Not Start" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Engine Idles With Rough Acceleration At Load, Not Able to Reach Full Power or Misses

Test Step	Result	Action to Take
1 Check for icing or freezing of the regulator. • With the engine at idle • Check for ice or frost build up on the converter casing and outlet port. **Is ice present?**	**Yes** **No**	The presence of ice on the converter with the engine running, indicates the possibility of a coolant supply problem. Check coolant level and the coolant system for leaks. Check for proper coolant type. Go to Step 2.
2 Check DEPR operation. • With the engine at idle • Disconnect the electrical connector **Is there a change in engine running with this unplugged?**	**Yes** **No**	Possible wiring issue, faulty ECU, or faulty DEPR, view page 9 of this section for wiring. Go to Step 3.
3 Check DEPR supply voltage • Key OFF • Disconnect DEPR electrical connector • Key ON • Check pins 3 and 6 for 12 volt supply in the harness **Is the voltage less than 11.5 volts?**	**Yes** **No**	12 volt DEPR circuit is open, shorted to gnd or the GCP module is faulty. Check wiring, connectors and fuses for possible causes. View page 9 of this section for wiring Go to step 4.
4 Check the vapor regulator operation • Engine OFF • Install a pressure gauge on the "Primary Pressure Test" port • Start and idle the engine **Did you NOT measure 3.5psi?**	**Yes** **No**	Regulator is malfunctioning, replace the regulator. Go to step 5.
5 Check fuel lock supply voltage. • Key Off • Disconnect fuellock connector from harness • Key On • Using a high impedance DVOM, check for 12 volt supply at the harness connector **Is the voltage less than 11.5 volts?**	**Yes** **No**	12 volt fuelock activation circuit is open, shorted to ground or the GCP module is faulty. Check wiring, connectors and fuses for possible cause. Go to step 6.
6 Check the carburetor air valve for binding • With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. Pressing on the diaphragm will move the valve. **Is the air valve binding?**	**Yes** **No**	Replace the mixer. May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Ensure all coils are firing. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

Diagnostic Aids

Fuel Lock Solenoid: The fuel lock is an electronic solenoid that is opened to allow fuel flow when the key is turned ON. High temperatures may cause the solenoid to become intermittent, not opening to supply sufficient fuel pressure.

Fuel Filter: There is a filter element located in the inlet of the fuel lock which may become clogged and limit fuel flow, especially at low tank pressures. Check the filter and replace as necessary.

Mixer Assembly (Carburetor): It is possible that a backfire may have caused the fuel valve to partially come off of its retainer and restrict fuel, check the mixer fuel valves, see section 475-1 for disassembly.

Fuel Line Restrictions: The vehicle specifications table specifies the fuel line to be a certain size. If the fuel line from the tank to the fuel lock is not the proper size, or any valves or fittings with flow restrictive characteristics are used, the fuel flow will not be sufficient to the converter with low tank pressure. Correct any fuel line or fitting restrictions.

Regulator Assembly: If no other problems have been identified, replace the fuel management assembly with a known good part of the same pressure range. Retest.

The pinpoint tests below should be performed after the preliminary tests and "Engine Backfires" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding

Engine Backfires

Test Step		Result	Action to Take
1	Check for icing or freezing of the regulator.	**Yes**	The presence of ice on the converter with the engine running, indicates the possibility of a coolant supply problem. Check coolant level and the coolant system for leaks. Check for proper coolant type.
• With the engine at idle • Check for ice or frost build up on the converter casing and outlet port. **Is ice present?**		**No**	Go to Step 2.
2	Check DEPR operation.		Possible wiring issue, faulty ECU, or faulty DEPR. View page 9 of this section for wiring
• With the engine at idle • Disconnect the electrical connector **Is there a change in engine running with this unplugged?**		**Yes** **No**	Go to Step 3.
3	Check DEPR supply voltage	**Yes**	12 volt DEPR circuit is open, shorted to gnd or the GCP module is faulty. Check wiring, connectors and fuses for possible causes. View page 9 of this section for wiring
• Key OFF • Disconnect DEPR electrical connector • Key ON • Check pins 3 and 6 for 12 volt supply in the harness **Is the voltage less than 11.5 volts?**		**No**	Go to step 4.
4	Check the vapor regulator operation	**Yes**	Regulator is malfunctioning, replace the regulator.
• Engine OFF • Install a pressure gauge on the "Primary Pressure Test" port • Start and idle the engine **Did you NOT measure 3.5psi?**		**No**	Go to Step 5.
5	During startup, check for fuel lock leakage (not closing).		This would indicate the fuel lock is not closing and allowing fuel to pass in the OFF position. Replace the fuel lock.
• Close the tanks main fuel valve • Install a pressure gauge on the primary test port of the vapor regulator • Key Off • Slowly open the main fuel valve **Do you measure any fuel pressure?**		**Yes** **No**	May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Ensure all coils are firing. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

The pinpoint tests below should be performed after the preliminary tests and "Emission failure – Rick Mixture" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Emission Failure - Rich Mixture

Test Step		Result	Action to Take
1	Check for clogged or restricted air filter. • Remove air filter • Start the engine and re-check emission levels. **Has the (rich) emission failure been eliminated?**	**Yes** **No**	This would indicate a clogged air cleaner as the cause. Replace as necessary. Go to step 2.
2	Check the carburetor air valve for binding • With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. **Is the air valve binding?**	**Yes** **No**	Replace the mixer. Go to Step 3
3	Check DEPR operation • With the engine at idle • Disconnect the electrical connector **Is there a change in engine running with this unplugged?**	**Yes** **No**	DEPR is likely not malfunctioning. Possible wiring issue, faulty ECU, or faulty DEPR. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

The pinpoint tests below should be performed after the preliminary tests and "Emission failure – Lean Mixture" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Emission Failure - Lean Mixture

Test Step		Result	Action to Take
1	Check regulator fuel supply	**Yes**	The fuel filter may be restricting flow or the fuel lock may be intermittent. Go to step 2.
• Install pressure gauge on the primary test port of the vapor regulator • Start the engine to induce the failure **Is the primary pressure less than 3.5psi or fluctuating?**		**No**	Go to step 3.
2	Check fuel lock supply voltage.	**Yes**	12 volt fuelock activation circuit is open, shorted to ground or the GCP module is faulty. Check wiring, connectors and fuses for possible cause.
• Key Off • Disconnect fuellock connector from harness • Key On • Using a high impedance DVOM, check for 12 volt supply at the harness connector **Is the voltage less than 11.5 volts?**		**No**	Go to step 3.
3	Check DEPR operation	**Yes**	Go to Step 4
• With the engine at idle • Disconnect the electrical connector **Is there a change in engine running with this unplugged?**		**No**	Possible wiring issue, faulty ECU, or faulty DEPR
4	Check the carburetor air valve for binding	**Yes**	Replace the mixer.
• With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. **Is the air valve binding?**		**No**	May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Ensure all coils are firing. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

The pinpoint tests below should be performed after the preliminary tests and "Engine Overheats" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Engine Overheats

Test Step		Result	Action to Take
1	Check for icing or freezing of the regulator.	**Yes**	The presence of ice on the converter, with the engine running, indicates the possibility of a coolant supply problem. Check Coolant level and the coolant system for leaks. Check for proper coolant type.
• With the engine at idle • Check for ice or frost build up on the converter casing and outlet port. **Is ice present?**		**No**	Go to step 2.
2	Check the vapor regulator operation	**Yes**	Regulator is functioning properly
• Engine OFF • Install a pressure gauge on the "Primary Pressure Test" port • Start and idle the engine **Did you measure 3.5psi?**		**No**	Go to step 3
3	Check the carburetor air valve for binding	**Yes**	Replace the mixer.
• With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. **Is the air valve binding?**		**No**	Refer to section 5 for cooling system troubleshooting.

Diagnostic Aids

Regulator Assembly (Converter & FCV): Overheating is typically related to a cooling or coolant problem. There is a possibility of a gasket leak inside the regulator, which would allow coolant to pass through to the fuel supply. This may affect the emissions if large enough. In this situation the coolant level should consistently drop, as coolant is lost through the fuel path. If no other problems have been identified, replace the fuel management assembly with a known good part of the same pressure range. Retest.

The pinpoint tests below should be performed after the preliminary tests and "Engine stops running and dies" chart Steps 1-3. Any electrical diagnostics should have been performed to eliminate any sensor, GCP or solenoid valve problems before proceeding.

Engine Stops Running (Dies)

Test Step		Result	Action to Take
1	Check for icing or freezing of the regulator. • With the engine at idle • Check for ice or frost build up on the converter casing and outlet port. **Is ice present?**	**Yes** **No**	The presence of ice on the converter, with the engine running, indicates the possibility of a coolant supply problem. Check Coolant level and the coolant system for leaks. Check for proper coolant type. Go to step 2.
2	Check regulator fuel supply • Install pressure gauge on primary test port of vapor regulator. • Start the engine to induce the failure **Is the primary pressure less than 3.5 psi or fluctuating?**	**Yes** **No**	The fuel filter may be clogged or the fuel lock may be intermittent. Go to step 3. Go to step 4
3	Check fuel lock supply voltage. • Key Off • Disconnect fuellock connector from harness • Key On • Using a high impedance DVOM, check for 12 volt supply at the harness connector **Is the voltage less than 11.5 volts?**	**Yes** **No**	12 volt fuelock activation circuit is open, shorted to ground or the GCP module is faulty. Check wiring, connectors and fuses for possible cause. Go to step 4.
4	Check the carburetor air valve for binding • With the air cleaner removed, pull the air valve piston upwards to ensure free movement of the carburetor air valve. **Is the air valve binding?**	**Yes** **No**	Replace the mixer. May be electronic, check that the CAM and crank sensor are not damaged and as well as all wiring. Ensure all coils are firing. Check if faults are present with the GCP diagnostic software. Refer to section 8, engine controls.

Diagnostic Aids

Fuel Lock Solenoid : The fuel lock is an electronic solenoid that is opened to allow fuel flow when the key is turned ON. High temperatures may cause the solenoid to become intermittent, not opening to supply sufficient fuel pressure.

Fuel Filter: There is a filter element located in the inlet of the fuel lock which may become clogged and limit fuel flow, especially at low tank pressures. Check the filter and replace as necessary.

Fuel Line Restrictions: The vehicle specifications table specifies the fuel line to be a certain size. If the fuel line from the tank to the fuel lock is not the proper size, or any valves or fittings with flow restrictive characteristics are used, the fuel flow will not be sufficient to the converter with low tank pressure. Correct any fuel line or fitting restrictions.

Mixer Assembly (Carburetor): It is possible that a backfire may have caused the fuel valve to partially come off of it's retainer and restrict fuel, check the mixer fuel valves.. Also check the mixer adapter plates for leakage past the carburetor.

Regulator Assembly (Converter & FCV): If no other problems have been identified, replace the fuel management assembly with a known good part of the same pressure range. Retest.

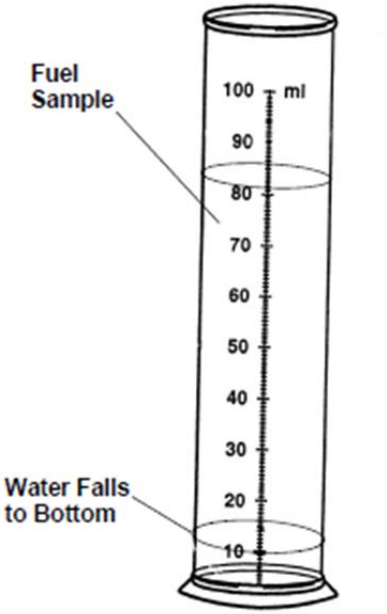
DIAGNOSIS AND TESTING – GASOLINE

NOTE: For diagnosis of Electronic Engine Control - refer to Section 08.

Visual Inspection

Check for dirt or water in the fuel tank. Water and dirt that accumulate in the fuel tank can cause a restricted fuel line, filter or a malfunction of the fuel pump.

Condensation, which is the greatest source of water entering the fuel tank, is formed by moisture in the air when it strikes the cold interior walls of the fuel tank.



Check the fuel filter. If the accumulation of dirt and water in the filter is excessive, the fuel tank should be removed and flushed, and the line from the fuel pump to the tank should be blown out.

Check fuel lines for damage. Air leakage in the fuel inlet line can cause low fuel pump pressure and volume.

Check fuel tank vent. A restricted fuel tank vent can cause low fuel pump pressure and volume and can result in collapsed inlet hoses or a collapsed fuel tank. High or low pressure are the two most likely fuel pump troubles that will affect engine performance. Low pressure will cause a lean mixture and fuel starvation at high speeds, and excessive pressure will cause high fuel consumption and possible flooding.

Fuel Pressure Check

WARNING: REFER TO WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Connect to the GCP display
2. Put the key in the on position.
3. On the faults page check the fuel pressure by cycling the keyswitch.
4. Fuel pressure should be as follows:
    a. Key on, Engine off (first 50 seconds): 60psia
    b. Engine running:60psia

Note: Refer to the engine controls section for GCP display setup and installation.

To check the actual fuel pressure, a gauge will have to be installed in-line of the fuel system close the fuel rail.

- Fuel pressure should be as follows:
    - Key on, Engine off (first 50 seconds): 45psig
    - Engine running: 45psig

If fuel pressure is insufficient, check for a clogged pump filter, screen or fuel filter. Also check for a break or restriction in the fuel lines. If fuel pump is inoperative, check for damaged or loose ground or improper wiring. Make sure fuel lines connections area tight and not leaking.

Note: The GCP is reading fuel pressure at the fuel block located after the fuel pump.

Fuel Pump Check

The fuel pump is modulated with a PWM signal from the GCP to precisely control the fuel pressure to the injectors. The positive side of the fuel pump will always have 12 volts with the engine running which is supplied from the fuel pump relay.

- PWM signal from the GCP is Pin 90
- If 12 volts is present ensure the wirings to the GCP for the PWM signal. If wiring is ok, possible faulty GCP.

Fuel Block Check

The fuel block monitors the fuel pressure and fuel temperature, which is what the GCP display is reading.

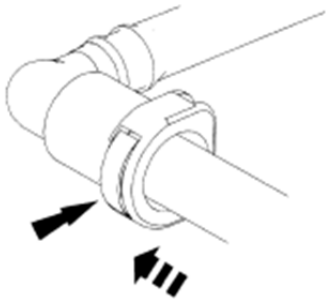
- Check wiring from the fuel block to the main engine harness
- If damaged replace the fuel block jumper harness
- Bad or diesel fuel can damage this component. Replace if known fuel contamination.
- Grounding out the fuel pump can cause the fuel pump to output ~120psia. If this is done and the GCP display does not read the higher pressure then the sensor is possibly bad. Check the wiring and if that is ok, replace the fuel block.
- If a gauge is installed in-line of the fuel rail, this reading can be checked against the fuel pressure read in the GCP display. If these do not match then a possible faulty fuel block sensor.

Quick Connect Coupling - Type I - Disconnect

WARNING: REFER TO WARNINGS AT THE BEGINNING OF THIS SECTION.

CAUTION: Do not use any tools. Use of tools may cause a deformity in the coupling components which can cause fuel leaks.

1. Relieve the fuel system pressure -- Refer to “Fuel Pressure Relief” on page 31 of this section.
2. Press the fuel tube quick connect coupling button and pull fuel tube to disconnect.



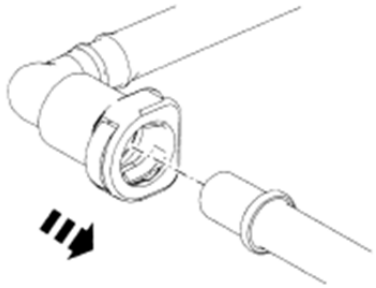
Quick Connect Coupling - Type I - Connect

1. Inspect for damage and clean fittings.

CAUTION: Make sure the fuel tube clicks into place when installing the tube. To make sure that the fuel tube is fully seated, pull on the tube.

2. Lubricate the o-ring seals with clean engine oil.

3. Install the quick connect coupling onto the tube until it is fully seated.



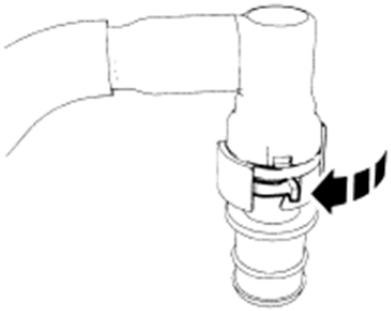
4. Pull on the fitting to make sure it is fully engaged.

Quick Connect Coupling - Type II - Disconnect

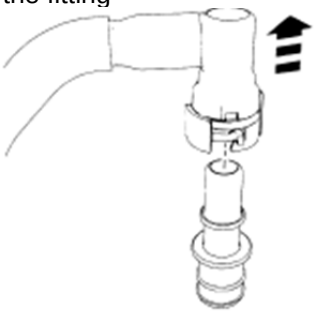
WARNING: REFER TO WARNINGS AT THE BEGINNING OF THIS SECTION.

CAUTION: Do not use any tools. Use of tools may cause a deformity in the coupling components which can cause fuel leaks.

1. Relieve the fuel system pressure -- Refer to “Fuel Pressure Relief” on page 31 of this section.
2. Release the locking tab on the quick connect coupling.



3. Separate the quick connect coupling from the fitting

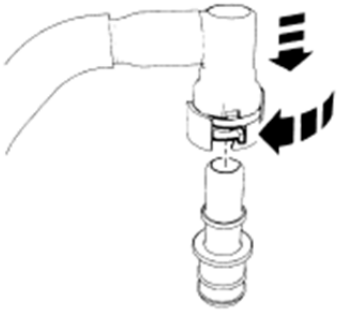


Quick Connect Coupling - Type II – Connect

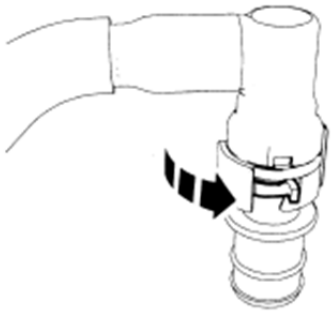
1. Inspect for damage and clean fittings.

CAUTION: Make sure the fuel tube clicks into place when installing the tube. To make sure that the fuel tube is fully seated, pull on the tube.

2. Lubricate the o-ring seals with clean engine oil.
3. Release the locking tab and install the quick connect coupling onto the fitting.



4. Position the locking tab into the latched position.



5. Pull on the fitting to make sure it is fully engaged.

REMOVAL AND INSTALLATION

Fuel Rail & Injectors - Replacement

WARNING: DO NOT SMOKE OR CARRY LIGHTED TOBACCO OR OPEN FLAME OF ANY TYPE WHEN WORKING ON OR NEAR ANY FUEL-RELATED COMPONENT. HIGHLY FLAMMABLE MIXTURES ARE ALWAYS PRESENT AND MAY BE IGNITED, RESULTING IN POSSIBLE PERSONAL INJURY.

WARNING: FUEL IN THE FUEL SYSTEM REMAINS UNDER HIGH PRESSURE EVEN WHEN THE ENGINE IS NOT RUNNING. BEFORE WORKING ON OR DISCONNECTING ANY OF THE FUEL LINES OR FUEL SYSTEM COMPONENTS, THE FUEL SYSTEM PRESSURE MUST BE RELIEVED. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

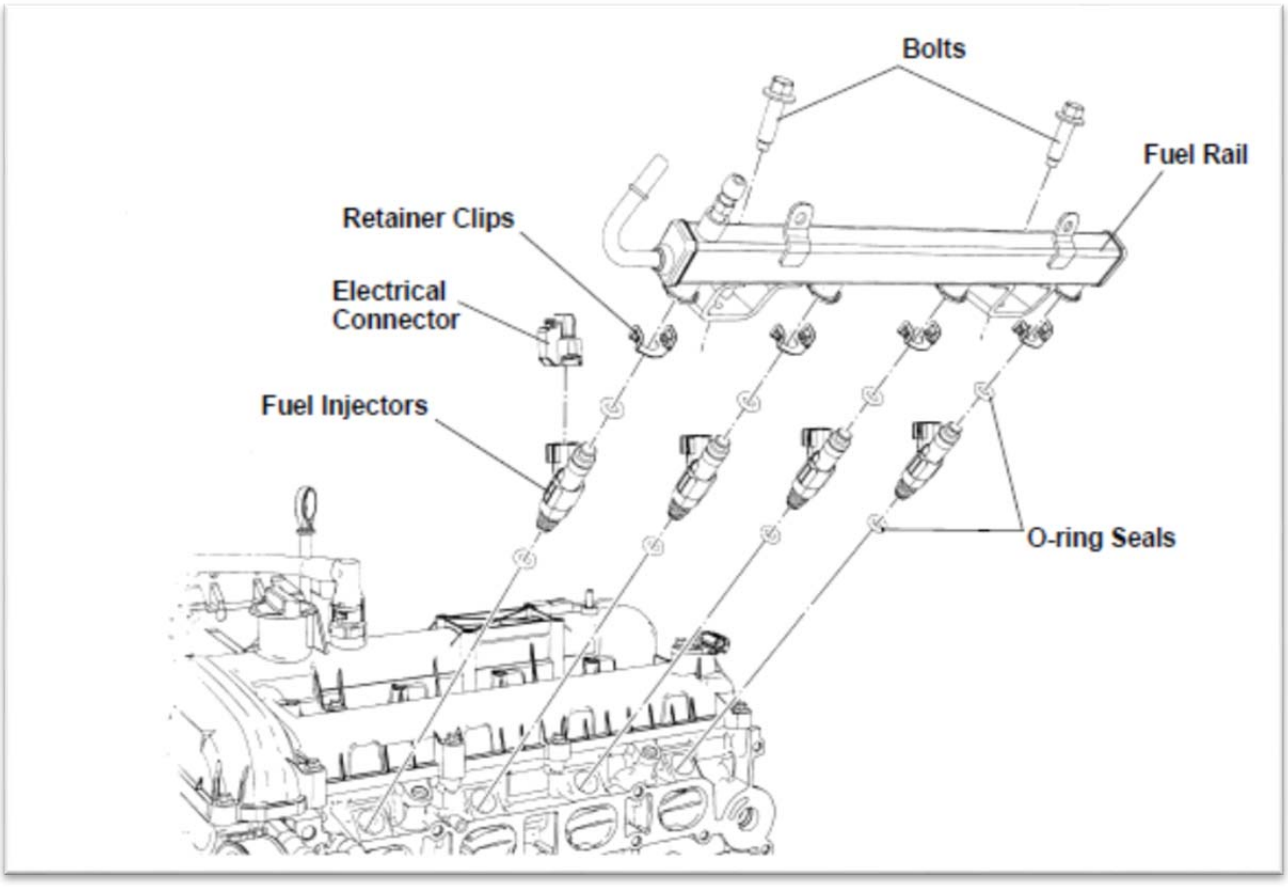
1. Disconnect the battery ground cable.
2. Remove and/or disconnect components to allow access and removal of the fuel rail & injectors. Label if necessary to allow for correct reinstallation.

CAUTION: After disconnecting fuel lines, plug the ends to prevent fuel leakage.

3. Disconnect fuel lines -- Refer to “General Service Procedures” on page 31of this section.
4. Disconnect injector electrical connectors.
5. Remove bolts.
6. Carefully remove the fuel rail and injector assembly
7. If necessary, remove the retaining clips and separate the fuel injectors from the fuel rail – discard the o-rings.

CAUTION: Use o-ring seals that are made of special fuel-resistance material. The use of ordinary o-rintg seals can cause the fuel system to leak. Do not reuse the o-ring seals

8. Reverse procedure to install:
   - Lubricate new o-rings with clean engine oil
   - Tighten fuel rail bolts to 25 Nm (18 lb-ft).



Actuator - Removal

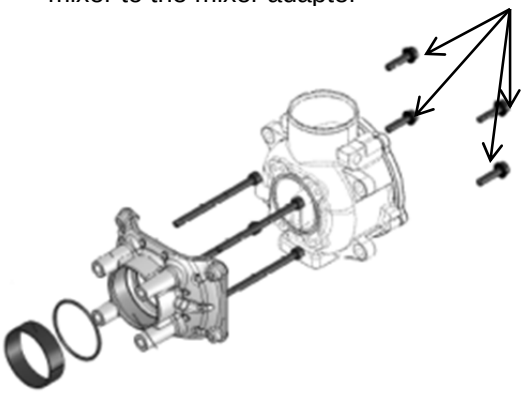
1. Remove and/or disconnect components to allow access and removal of the actuator. Label if necessary to allow for correct reinstallation.
2. Disconnect air cleaner components from actuator.
3. Disconnect accelerator cable.
4. Disconnect electrical connectors.
5. Remove nuts.
6. Remove actuator and gasket.

Actuator - Installation

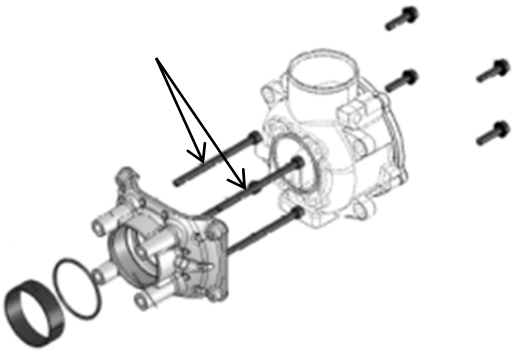
1. Inspect gasket and install a new one if necessary.
2. Position actuator onto studs.
3. Install nuts
    - Tighten to 8 ft-lb
4. Reconnect electrical connectors.
5. Reconnect accelerator cable.
6. Reconnect air cleaner components to actuator.
7. Install or connect any other component removed or disconnected.

Mixer - Removal

1. Remove top four bolts that hold the mixer to the mixer adapter



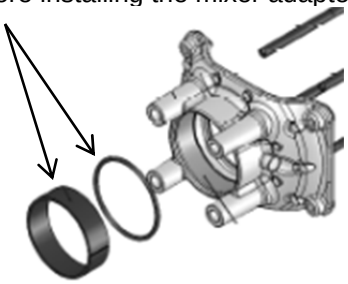
2. To Remove the Mixer adapter, unscrew the four bolts. This will also unmount the actuator



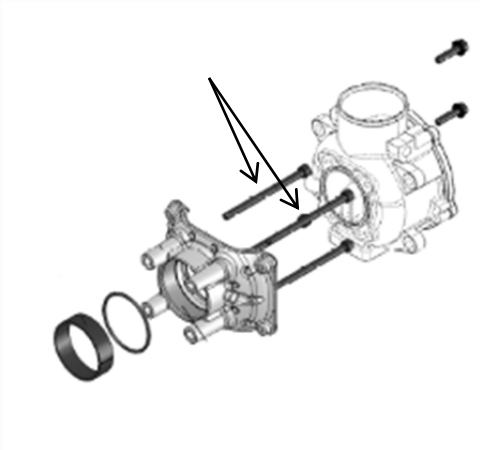
3. The DEPR can also be disconnected from the mixer via the four mounting bolts.

Mixer - Installation

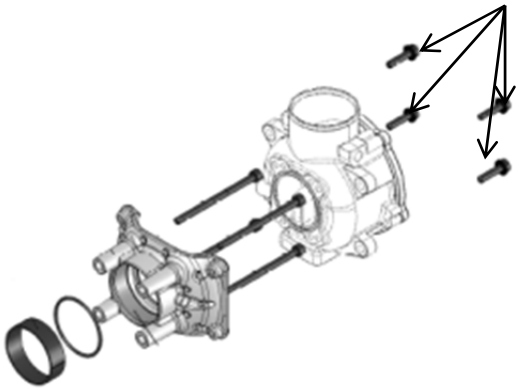
1. Reverse the removal procedure. Ensure to install the two gaskets on the actuator before installing the mixer adapter.



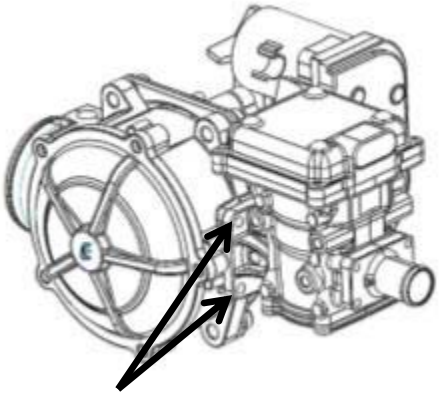
2. Mount the actuator with the mixer adapter using the four 85mm long M6x1.0 bolts. Ensure the gasket for the actuator is not damaged.
    - Tighten to 6.6lb-ft



3. Mount the mixer to the mixer adapter using the four short M6x1.0 bolts. Ensure the gasket on the mixer is not damaged.
    - Tighten to 6.6 lb-ft



4. Mount the DEPR to the mixer (if uninstalled). Ensure the rubber gasket on the DEPR is not damaged.
    - Tighten to 35 lb-in (4Nm)



Specifications

GENERAL SPECIFICATIONS	
Fuel Pressure	414-448kPA (60-65psi)
Motorcraft SAE 5W20 Super Premium	WSS-M2C930-A

Torque Specifications			
Description	Nm	Lb.ft.	Lb.in
Fuel Rail Bolts	25	18	

TSG-416 COOLING SYSTEM

INDEX

Subject	Page
General Information	
Description	05 – 3
Diagnosis and Testing	
Visual Inspection	05 – 4
Coolant Inspection	05 – 4
Coolant Range Check	05 – 4
Drive Belt Inspection	05 – 5
Symptom Chart	05 – 6
Cooling System Pressure Test	05 – 7
Radiator Cap Pressure Test	05 – 7
Thermostat Operational Check	05 – 7
General Service Procedures	
Draining the Cooling System	05 – 8
Flushing the Cooling System	05 – 8
Filling the Cooling System	05 – 8
Removal and Installation	
Drive Belt – Removal	05 – 9
Drive Belt – Installation	05 – 9
Belt Tensioner – Replacement	05 – 9
Idler Pulley – Replacement	05 – 9
Radiator Hose – Removal	05 – 10
Radiator Hose – Installation	05 – 10
Thermostat & Housing – Replacement	05 – 11
Coolant Pump – Replacement	05 – 12
Outlet Pipe – Replacement	05 – 13
Coolant Bypass – Replacement	05 – 14
Specifications	**05 - 15**

TSG-416 COOLING SYSTEM

CAUTIONS & WARNINGS

WARNING: THE RADIATOR OR DEGAS TANK IS EQUIPPED WITH A PRESSURE CAP. IT IS DANGEROUS TO REMOVE THIS WHEN THE SYSTEM IS VERY HOT.

WARNING: NEVER REMOVE THE PRESSURE RELIEF CAP WHILE THE ENGINE IS OPERATING OR WHEN THE COOLING SYSTEM IS HOT. MAY CAUSE PERSONAL INJURY OR DAMAGE TO COOLING SYSTEM OR ENGINE. TO REDUCE THE RISK OF HAVING SCALDING HOT COOLANT OR STEAM BLOW OUT OF THE DEGAS BOTTLE WHEN REMOVING THE PRESSURE RELIEF CAP, WAIT UNTIL THE ENGINE HAS COOLED DOWN TO AT LEAST 40°C (110°F).

1. Wrap a thick cloth around the pressure relief cap and turn it slowly one-half turn counterclockwise. Stepping back while the pressure is released from the cooling system.
2. When you are sure all the pressure has been released, (still with a cloth) turn counterclockwise and remove the pressure relief cap.

WARNING: ANTIFREEZE CONTAINS MONO ETHYLENE GLYCOL AND OTHER CONSTITUENTS WHICH ARE TOXIC IF TAKEN INTERNALLY AND CAN BE ABSORBED IN TOXIC AMOUNTS ON REPEATED OR PROLONGED SKIN CONTACT. PERSONS USING ANTIFREEZE ARE RECOMMENDED TO ADHERE TO THE FOLLOWING PRECAUTIONS:

- **ANTIFREEZE MUST NEVER BE TAKEN INTERNALLY. IF ANTIFREEZE IS SWALLOWED ACCIDENTALLY, MEDICAL ADVICE SHOULD BE SOUGHT IMMEDIATELY**
- **PRECAUTIONS SHOULD BE TAKEN TO AVOID SKIN CONTACT WITH ANTIFREEZE. IN THE EVENT OF ACCIDENTAL SPILLAGE ONTO THE SKIN, ANTIFREEZE SHOULD BE WASHED OFF AS SOON AS PRACTICABLE. IF CLOTHING IS SPLASHED WITH ANTIFREEZE, IT SHOULD BE REMOVED AND WASHED BEFORE BEING WORN AGAIN, TO AVOID PROLONGED SKIN CONTACT.**
- **FOR REGULAR AND FREQUENT HANDLING OF ANTIFREEZE, PROTECTIVE CLOTHING (PLASTIC OR RUBBER GLOVES, BOOTS AND IMPERVIOUS OVERALLS OR APRONS) MUST BE USED TO MINIMIZE SKIN CONTACT.**

CAUTION: Under no circumstances should the engine be started without liquid in the cooling system. This may cause permanent damage to the engine.

CAUTION: The use of straight water as a coolant will cause permanent damage to the engine.

CAUTION: Never use a cold coolant mixture to topup the radiator or degas tank of a hot engine if the coolant level is very low; this could cause serious engine damage.

CAUTION: In territories where freezing conditions may occur, the coolant should consist of a mixture of 50% plain water and 50% Motorcraft Premium Gold coolant, or equivalent. This antifreeze contains additional corrosion inhibitors designed to provide lasting protection for the engine.

CAUTION: Only this antifreeze, or proprietary antifreeze meeting Ford specification WSS-M97B51-A1 should be used when topping-up or re-filling the cooling system. Do not mix coolant types.

CAUTION: Do not add or mix an orange-colored extended life coolant, such as Motorcraft Specialty Orange engine coolant with factory filled coolant WSS-M97B44-D. Mixing Motorcraft Specialty Orange engine coolant or any orange colored extended life product, with factory filled coolant, can result in degraded corrosion protection.

CAUTION: If there is engine coolant in the engine oil or transmission fluid, the cause must be corrected and oil/fluid changed or major component damage can occur.

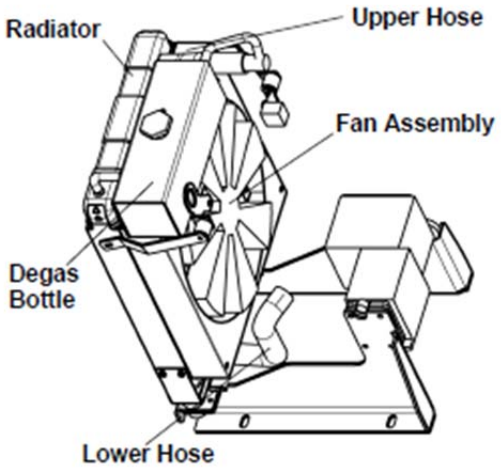
CAUTION: When removing coolant, the coolant must be recovered in a suitable, clean container for reuse. If the coolant is contaminated, it must be recycled
or disposed of correctly.

WARNING: DO NOT STAND INLINE WITH OR NEAR THE ENGINE COOLING FAN BLADE WHEN REVVING THE ENGINE. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

CAUTION: Under no circumstances should the drive belt, tensioner or pulleys be lubricated as potential damage to the belt material and tensioner dampening mechanism will occur. Do not apply any fluids or belt dressing to the drive belt or pulleys.

TSG-416 COOLING SYSTEM

GENERAL INFORMATION



Description

The cooling system consists of the following:

- Engine Coolant Temperature (ECT) Sensor
- Fan Assembly
- Radiator and Cap
- Thermostat and Housing
- Degas Bottle
- Engine Block Heater
- Coolant pump
- Coolant

Walter C. Avrea, the owner of patents 3,601,181 and RE27,965, has granted Ford Motor Company rights with respect to cooling systems covered by these patents.

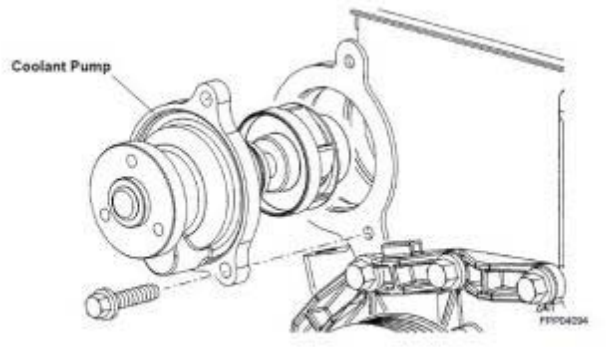
The ECT Sensor is used by the GCP to obtain coolant temperature information. Refer to Section 8 for further information on this sensor.

The coolant fan blade can either draw or push air through the radiator to help cool the system coolant.

The radiator allows excess heat to be transferred to the air. The radiator tanks cannot be repaired. The radiator cap maintains system pressure. This pressure raises the boiling point of the coolant and helps prevent vapor locks in the engine block and cooling system.

The thermostat prevents coolant flow until it reaches a specified temperature. At this temperature, it will open and allow coolant flow through the engine and radiator.

The thermostat and housing are serviced as a unit. The radiator degas bottle holds a surplus coolant when the engine is hot. It also replenishes coolant back to the system as it cools. The degas bottle allows air separation during operation which reduces engine hot spots.



The coolant pump circulates the coolant through the engine block and cylinder heads to the thermostat. If th thermostat is closed, the coolant returns to the coolant pump through a bypass hose. Once the coolant reaches a specified temperature, the thermostat will open, allowing the coolant to flow to the radiator for heat transfer and back to the coolant pump inlet.

Engine coolant provides freeze and boil protection to the engine and cooling components. In order to obtain these protections, the engine coolant must be maintained at the correct concentration and fluid level in the degas bottle or coolant expansion tank.

Coolant is made up of a 50/50 mix of ethylene glycol permanent antifreeze and water. This mixture is to be used year-round with temperatures above -34.4°C (-30°F). If recycled coolant is used, it must meet Ford specification ESE-M97B44-A or WSSM97B44-D.

CAUTION: Not all coolant recycling processes produce coolant which meets Ford specification ESEM97B44- A or WSS-M97B44-D. Use of coolant that does not meet specifications may harm engine and cooling system components.

CAUTION: Do not use alcohol type antifreeze, alkaline brine solutions, or 100,000 mile, red in color antifreeze. This may cause serious engine cooling system damage.

DIAGNOSIS AND TESTING

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

Begin diagnosis by verifying the customer's concern by operating the engine to duplicate the condition. The most frequent cooling system complaints are leakage and overheating. Either of these problems will soon render the engine inoperable.

Perform a visual inspection. If the inspection reveals an obvious concern that can be readily identified, repair as necessary. If the concern remains after the inspection, determine the symptom(s) and go to the Symptom Chart. The Symptom Chart lists cooling system problems, their possible cause and recommended correction.

Visual Inspection

Check for leaks or damage at:

- all hoses, connections and hose clamps
- radiator seams, core and drain petcock
- all block core plugs and drain plugs
- edges of all cooling system gaskets
- transmission oil cooler (if equipped)
- coolant pump shaft and bushing
- thermostat, head and intake manifold gaskets
- coolant pump
- degas bottle
- heater core (if equipped)
- fan and fan clutch
- engine coolant temperature sensor and wiring
- drive belt.

NOTE: A small amount of antifreeze coming out the coolant pump weep hole may be considered normal.

Examine oil dipstick for evidence of coolant contaminated engine oil (white milky appearance). Check radiator for evidences of oil in coolant (leakage at transmission oil cooler if equipped).

Some engines use an ethylene glycol base antifreeze solution to which the manufacturers have added a dye color. The dye color makes the antifreeze solution an excellent leak detector. If this type of solution is not being used in the cooling system, a vegetable dye may be added to aid in locating external leakage.

Coolant Inspection

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

Check level and condition of coolant:

- A dark brown color could indicate a stop leak was used.
- A light or reddish brown color indicates that rust may be present in the cooling system. Flush the system and refill with the correct mixture of distilled water and premium engine coolant.
- An iridescent sheen on top of the coolant could indicate a trace of oil is entering the system.
- A milky brown color may indicate that either engine oil or transmission fluid is entering the cooling system. If transmission fluid is suspected, it may be entering through the transmission cooler in the radiator. If engine oil is suspected, the cause may an internal leak in the engine.

Coolant Range Check

If the engine coolant appearance is acceptable, test the engine coolant freezing point and concentration level.

The antifreeze concentration in a cooling system can be determined by using a suitable hydrometer or a battery/ antifreeze tester.

The freezing point should be in the range -45°C to -23°C (-50°F to -10°F). If the equipment is run in cold climates colder than -36°C (-34°F), it may be necessary to increase the coolant concentration to get adequate freeze protection.

Maximum coolant concentration is 60% coolant to 40% distilled water. If coolant tests too strong, remove some of the coolant and ad distilled water until the readings are acceptable.

Minimum coolant concentration is 40% coolant to 60% distilled water. If coolant tests too weak, drain some coolant out and add straight coolant until readings are acceptable.

Drive Belt Inspection

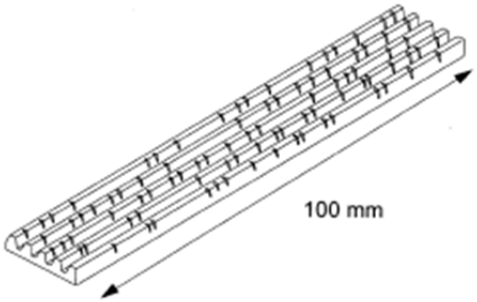
⚠

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

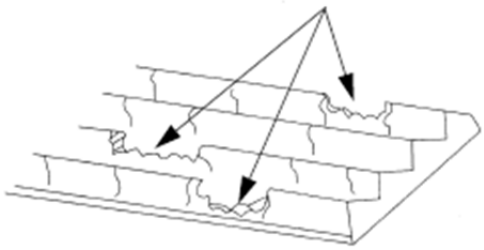
With engine running, observe the belt movement. It should respond when engine is accelerated rapidly. If tensioner moves excessively without rapid acceleration, install a new belt. If excessive movement still exists, install a new tensioner.

Visually inspect the belt for obvious signs of damage.

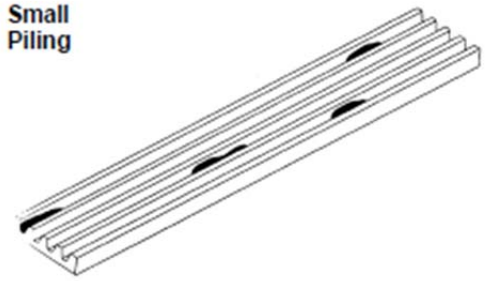
- Up to 15 cracks in a rib over a distance of 100 mm (4.0 in) can be considered acceptable.



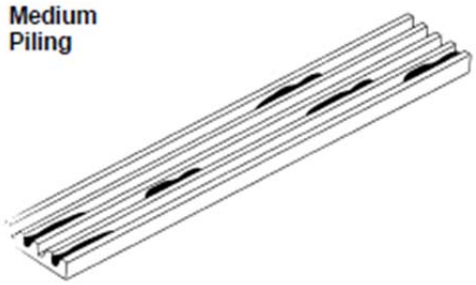
- If cracks are beyond acceptable or, any chunks are found to be missing from the ribs, a new belt must be installed.



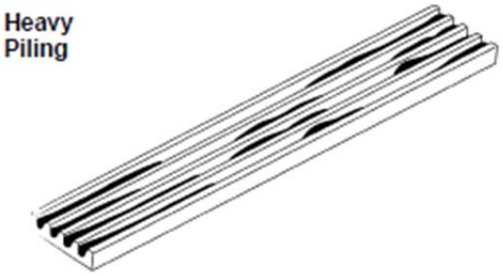
- Small scatted deposits of rubber material (known as piling) are not a concern.



- Longer deposits building up to 50% of the rib height is also not a concern, except it can result in excessive noise.



- If heavy deposits are apparent, resulting in noise and belt instability, install a new belt.



- Drive belt squeal that is short and intermittent is expected and considered normal. Constant or reoccurring drive belt squeal can occur with a damaged pulley bearing, fluid contamination, or a loose belt.

- Also check for belt misalignment which can cause a chirping noise. If misalignment is found, check the tensioner for damage, especially the mounting pad surface. Check for a damaged pulley that wobbles. Check mounting brackets for tightness and for any interference.

- Check tensioner with a suitable release tool that it moves without sticking or binding.

- With belt off, check that all pulleys rotate freely without binding.

CAUTION: Incorrect drive belt installation will cause excessive drive belt wear and can cause the belt to come off the pulleys.

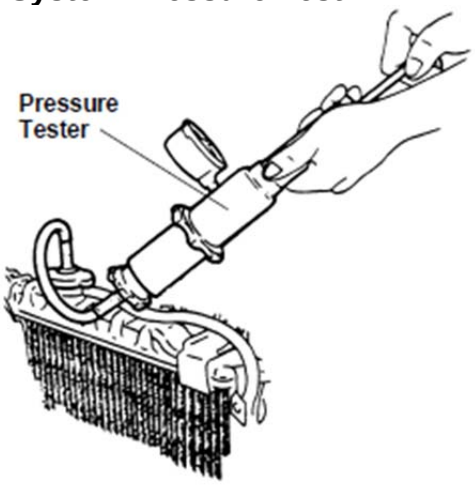
Symptom Chart

Refer to the following Diagnosis chart for cooling system problems, their possible cause and recommend correction.

CONDITION	POSSIBLE SOURCE	ACTION
Loss of coolant	• Pressure cap and gasket • Leakage • External leakage • Internal leakage	• Inspect, wash gasket and test. Replace only if cap will not hold pressure to specification. • Pressure test system. • Inspect hose, hose connection, radiator, edges of cooling system gaskets, core plugs and drain plugs, transmission oil cooler lines, water pump, heater system components. Repair or replace as required. • Disassembly engine as necessary – check for: cracked intake manifold, blown head gaskets, warped head or block gasket surfaces, cracked cylinder head or engine block.
Engine Overheats	• Low coolant level • Loose fan belt • Pressure cap • Radiator obstruction • Closed thermostat • Fan drive clutch • Ignition • Temp gauge or cold light • Engine • Coolant mixture	• Fill as required. Check for coolant loss. • Adjust. • Test. Replace if necessary. • Remove bugs, leaves, etc. • Test, Replace if necessary. • Test, replace if necessary. • Check timing and advance. Adjust as required. • Check electrical circuits and repair as required. • Check water pump, block for blockage. • 1/2 water and 1/2 permanent anti-freeze mixture.
Engine fails to reach normal operating temperature	• Open thermostat • Temperature gauge or cold light	• Test, replace if necessary. • Check electrical circuits and repair as required.

TSG-416 COOLING SYSTEM

Cooling System Pressure Test



WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Remove the radiator cap from the radiator filler neck.

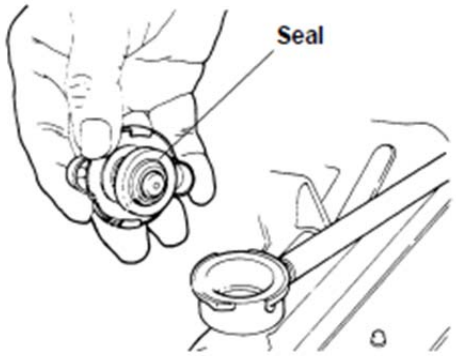
CAUTION: Do not pressurize the cooling system beyond 138 kPa (20 psi).

2. Fill the radiator as needed.
3. Fit the pressure tester to the radiator neck.
4. Pump the cooling system to a maximum of 138 kPa (20 psi) and hold for 2 minutes.
5. If the pressure drops within this time, inspect for leaks and repair as necessary.

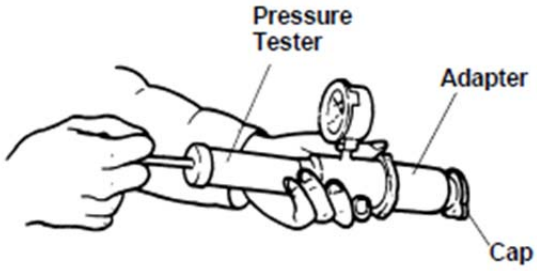
Radiator Cap Pressure Test

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Inspect radiator cap and seals for damage or deterioration - replace as necessary.



2. Fit the radiator cap to the pressure tester using an adapter.



NOTE: If the plunger of the pressure tester is depressed too fast, an incorrect pressure reading will result.

3. Slowly pump the pressure tester until the gauge stops increasing and note the highest pressure reading.

4. Release the pressure and repeat the test.

5. Install a new radiator cap if the pressure is not 124 kPa (18 psi).

Thermostat Operational Check

1. Hold thermostat up to the light.

2. Visually check the valve to be sure it is air tight.
   - Leakage of light all around the valve (at room temperature) indicates a bad thermostat.
   - A slight leakage of light at one or two locations on the perimeter of the valve is normal.

3. Place the thermostat and a thermometer in water.

4. Gradually increase the water temperature

5. Replace thermostat if it does not open at the specified temperatures:
   - Starts to open: 82°C (180°F)
   - Fully open: 97°C (206.6°F)

GENERAL SERVICE PROCEDURES

Draining the Cooling System

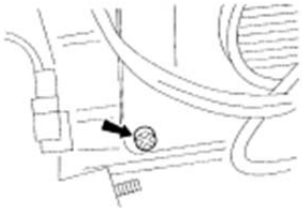
WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Remove radiator cap.

CAUTION: The coolant must be recovered in a suitable, clean container for reuse. If the coolant is contaminated, it must be recycled or disposed of correctly.

2. Open drain cock at radiator and drain old coolant from engine into a suitable container. Close the drain cock when finished

Radiator Drain Cock



3. If necessary, remove the lower radiator hose to completely drain the system. Reinstall when finished.

4. If rust, sludge or other foreign material are present in the old coolant, system should be flushed – Refer to “Flushing the Cooling System” instructions in this section.

Flushing the Cooling System

To remove rust, sludge and other foreign material from the cooling system, use Rotunda Cooling System Cleanser. Removal of such material restores cooling efficiency and avoids overheating.

Always remove the thermostat prior to pressure flushing. A pulsating or reversed direction of flushing water flow will loosen sediment more quickly than a steady flow in the normal direction of coolant flow.

In severe cases where cleaning solvents will not properly clean the cooling system for efficient operation, it will be necessary to use the pressure flushing method. Various types of flushing equipment are available. Follow manufacturer’s operating instructions.

Filling the Cooling System

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

Coolant is made up of a 50/50 mix of ethylene glycol permanent antifreeze and distilled water. This mixture is to be used year-round with temperatures above -34.4°C (-30°F). If recycled coolant is used, it must meet Ford specification ESE-M97B44-A or WSS-M97B44-D.

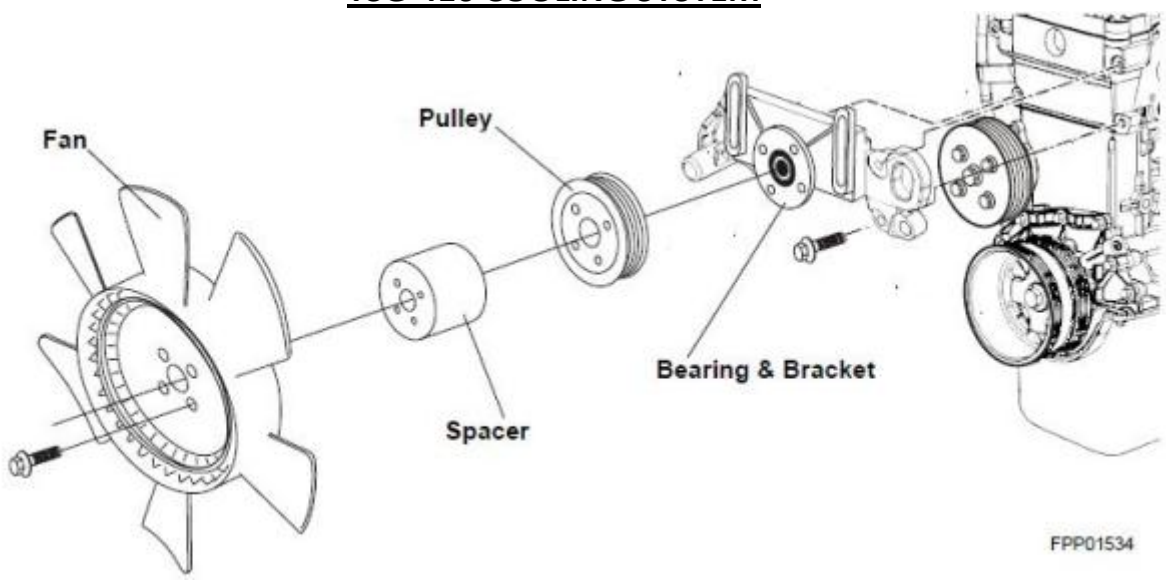
CAUTION: Not all coolant recycling processes produce coolant which meets Ford specification ESEM97B44- A or WSS-M97B44-D. Use of coolant that does not meet specifications may harm engine and cooling system components.

The engine cooling system is filled with Motorcraft Premium Gold Engine Coolant. Always refill the cooling system with the same coolant that was drained from the system, Do not mix coolant types.

CAUTION: Do not use alcohol type antifreeze, alkaline brine solutions, or 100,000 mile - red in color antifreeze. This may cause serious engine cooling system damage.

NOTE: The use of stop leak may change the color of the coolant.

1. Make sure the radiator drain cock is completely closed.
2. Fill the system with the proper coolant mix.
3. Start engine and hold at high idle engine speed for approximately 8 minutes until thermostat opens.
4. Maintain high idle for an additional 3 minutes. Add coolant as necessary.
5. Stop the engine and check for leaks.
6. Verify correct fluid level after engine cools for 20 minutes. Top off the degas bottle to “max” line.



REMOVAL AND INSTALLATION

NOTE: If a major component of the cooling system is renewed such as the radiator, water pump etc., the system should be flushed and re-filled with a 50% solution of Motorcraft Premium Gold engine coolant, or equivalent, and clean water -- Refer to “Flushing the Cooling System” on the previous page.

Fan Belt – Removal

1. Loosen two bolts holding fan bearing bracket in place.
2. Slide the bearing bracket down to loosen belt.
3. Remove belt

Drive Belt - Removal

NOTE: Note belt routing for installation purposes.

1. Loosen the tensioner.
2. Remove belt.
3. Inspect belt and pulleys -- Refer to “Visual Inspection” of this section.

Drive Belt - Installation

1. Route belt correctly and tighten the tensioner onto belt.
2. Run engine for a minute and then turn off.
3. Recheck belt routing and groove alignment.

Fan Belt – Installation

1. Place belt around the outer crank pulley (4 groove) and fan pulley
2. Slide bearing bracket up to tension the belt while ensuring the bearing bracket is level.
3. Tighten bearing bracket bolts.
    - 16Nm (12 lb-ft)

Belt Tensioner – Replacement

1. Remove drive belt -- Refer to “Drive Belt - Removal” above
2. Remove bolt.
3. Remove belt tensioner.
4. Reverse procedure to install:
    - Tighten bolt to 47 Nm (35 lb-ft).

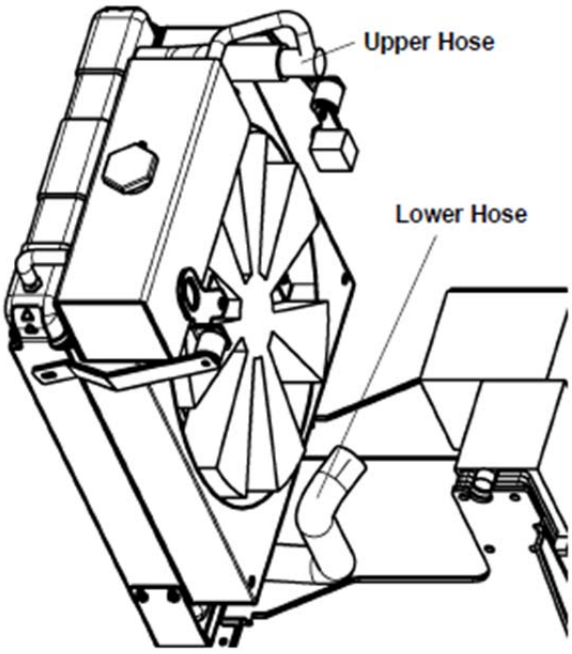
Idler Pulley - Replacement

1. Remove drive belt -- Refer to “Drive Belt - Removal” of this section.
2. Remove belt idler pulley assembly.
3. Reverse procedure to install:
    - Tighten to 47 Nm (35 lb-ft).

Radiator Hose - Removal

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.
2. Loosen the clamps at each end of the hose to be removed.
3. Slide the hose off the radiator connection and the engine water outlet connection.



Radiator Hose - Installation

1. Position the clamps at least 1/8 inch from each end of the hose.
2. Coat the connection areas with an approved water resistant sealer and slide the hose on the connection.

NOTE: Make sure the clamps are beyond the bead and placed in the center of the clamping surface of the connections.

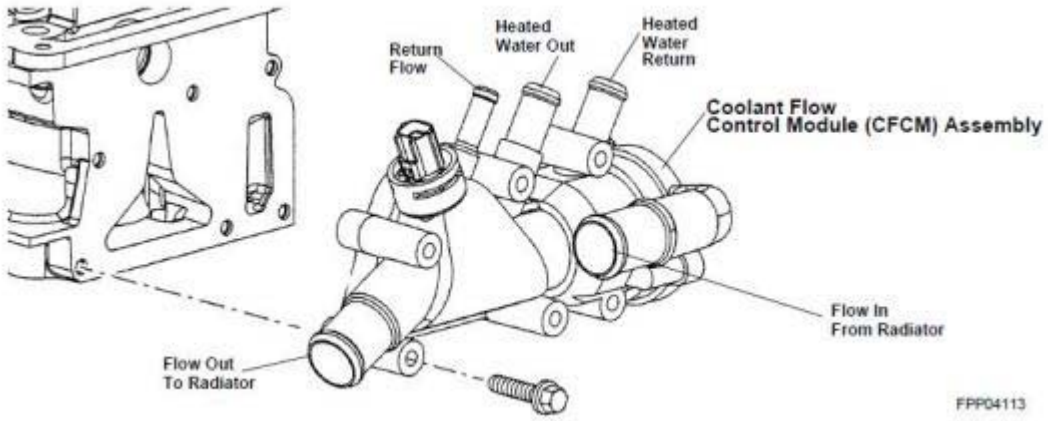
3. Tighten the clamps.
4. Fill the system with coolant -- Refer to “Filling the Cooling System” of this section.
5. Operate the engine for several minutes, then check the hoses and connections for leaks

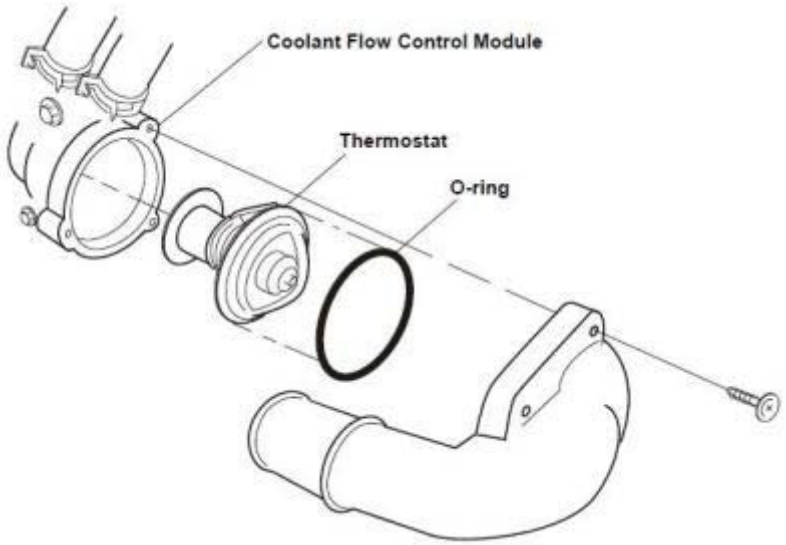
Thermostat & Housing – Replacement

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

NOTE: The thermostat and housing are serviced as an assembly.

1. Allow the engine to cool down until the coolant has lowered in temperature to below 110°F.
2. Drain the radiator so coolant level is below the thermostat -- Refer to “Draining the Cooling System” of this section.
3. Remove or disconnect components as necessary to gain access to the thermostat housing.
4. Disconnect the lower radiator hose.
5. Remove bolts and thermostat housing.
6. Reverse procedure to install
    - Clean and inspect gasket, install a new gasket if necessary.
    - Tighten bolts to 10 Nm (89 lb-in).

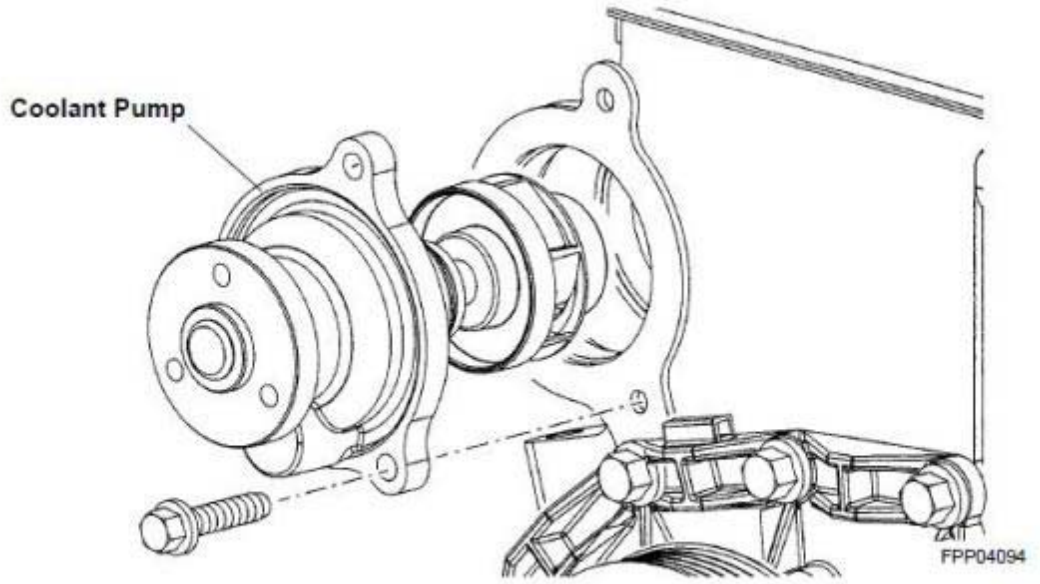




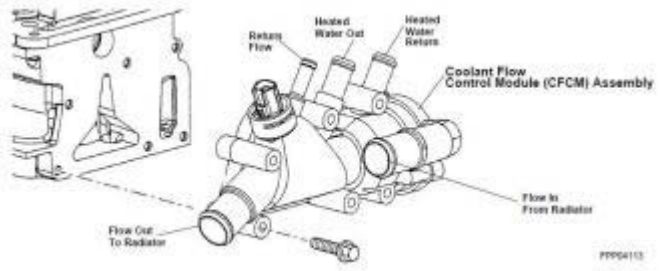
Coolant Pump - Replacement

WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.
2. Remove or disconnect components as necessary to gain access to the coolant pump.
3. Remove the drive belt -- Refer to “Drive Belt - Installation” of this section.
4. Remove 3 bolts and coolant pump pulley.
5. Remove 3 bolts and coolant pump.
6. Reverse procedure to install:
   - Lubricate coolant pump o-ring with clean coolant.
   - Tighten coolant pump bolts to 10 Nm (89 lb-in)
   - Tighten pulley bolts to 25 Nm (18 lb-ft)



Thermostat - Replacement



WARNING: REFER TO CAUTIONS AND WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.

2. Remove or disconnect components as necessary to gain access to the outlet pipe.

3. Disconnect hoses from outlet pipe.

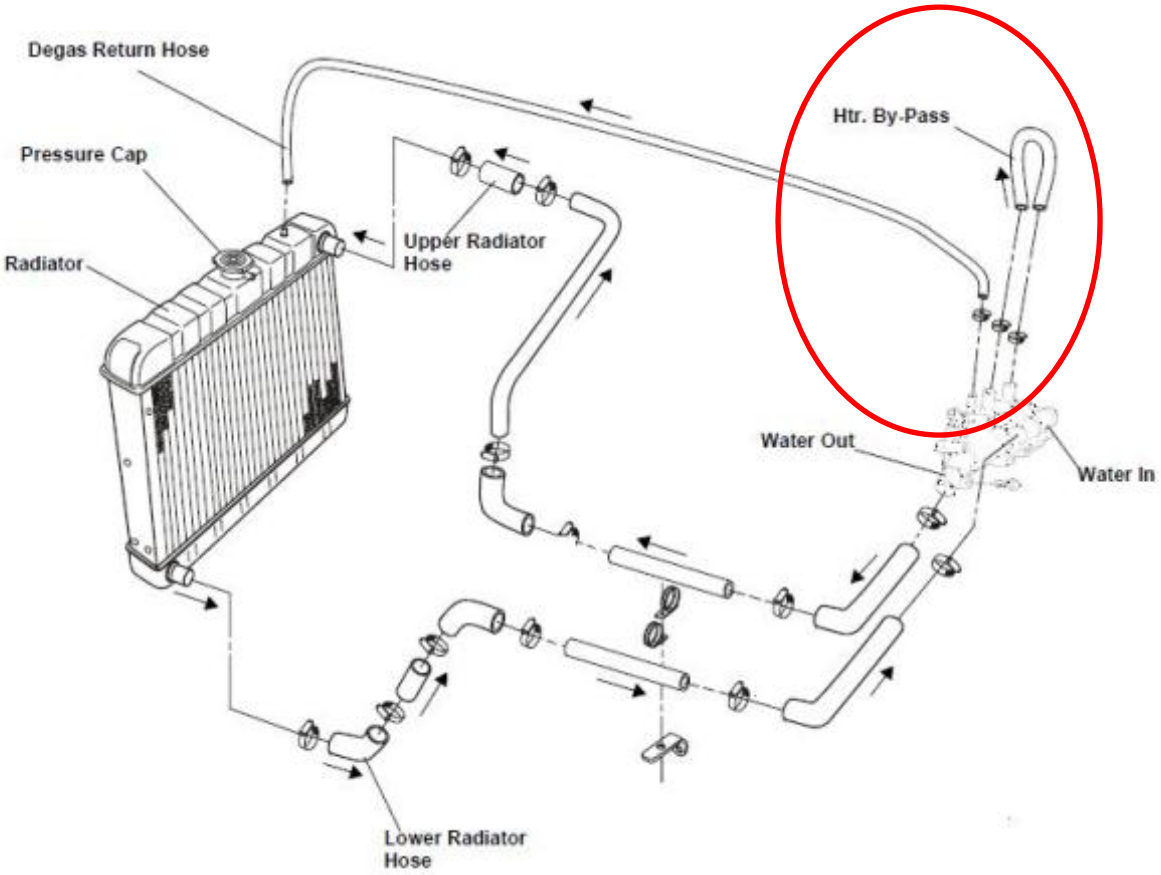
4. Disconnect electrical connector at ECT Sensor.

5. Remove bolts and outlet pipe.

6. Reverse procedure to install:
   - Clean gasket mating surfaces
   - Install new gasket
   - Tighten bolts to 10 Nm (89 lb-in).

Coolant Bypass – Replacement

1. Drain the cooling system -- Refer to “Draining the Cooling System” of this section.
2. Remove or disconnect components as necessary to gain access to the bypass hose
3. Disconnect the coolant bypass hose from the tubes.
4. Reverse procedure to install.



TSG-416 COOLING SYSTEM

GENERAL SPECIFICATIONS	
Coolant/Water Mixture	50/50
Pressure Relief Cap Opening Pressure kPa (psi)	89 – 124 kPa (13 – 18 psi)
Radiator Pressure Test	138 kPa (20 psi)
Thermostat start to open temperature	82°C (180°F)
Thermostat full open temperature	97°C (205°F)
Coolant Specification WSS-M97B51-A1	Motorcraft Premium Gold Engine Coolant

TORQUE SPECIFICATIONS			
Description	Nm	Lb-ft	Lb-in
Coolant pump pulley bolts	25	18	
Coolant pump to block bolts	10	---	89
Draincock	2	---	18
Thermostat housing bolts	10	---	89

TSG-416 CHARGING SYSTEM

INDEX

Subject

General Information **Page**

Description..... 06 – 3
Operation..... 06 - 3
Wiring Diagram..... 06 - 3

Diagnosis and Testing

Preliminary Checks..... 06 – 5
Warning indicator check..... 06 – 5
Symptom Chart..... 06 – 6
Battery Drain Test..... 06 – 7
Battery Load Test..... 06 – 7
Generator Output Test..... 06 – 8
Generator Voltage Test..... 06 – 8

General Service Procedures

Battery Cleaning and Inspection..... 06 – 9
Battery Tools..... 06 – 9
Battery Charging..... 06 – 10

Removal and Installation

Generator – Replacement..... 06 – 11
Voltage Regulator – Replacement..... 06 – 11
Generator Pulley – Replacement..... 06 – 12
Battery Removal..... 06 – 13
Battery Installation..... 06 – 13

Specifications..... **06 - 14**

Cautions & Warnings

Typical Battery Labeling

The handling and correct use of lead acid batteries is not as hazardous provided that sensible precautions are observed and that operatives have been trained in their use and are adequately supervised. It is important that all labeling on the battery is carefully read, understood and complied with. The format of the following symbols and labels is common to most brands of lead acid battery.

CAUTION: Observe all manufacturers' instructions when using charging equipment.

WARNING: BATTERIES NORMALLY PRODUCE EXPLOSIVE GASES WHICH CAN CAUSE PERSONAL INJURY. THEREFORE, DO NOT ALLOW FLAMES, SPARKS OR ANY IGNITED OBJECT TO COME NEAR THE BATTERY. WHEN CHARGING OR WORKING NEAR A BATTERY, ALWAYS SHIELDYOUR EYES. ALWAYS PROVIDE VENTILATION.

WARNING: WHEN LIFTING A BATTERY, ALWAYS LIFT WITH A BATTERY CARRIER OR WITH YOUR HANDS ON OPPOSITE CORNERS. EXCESSIVE PRESSURE ON THE END WALLS COULD CAUSE ACID TO SPEW THROUGH THE VENT CAPS, RESULTING IN PERSONAL INJURY.

WARNING: IT IS ESSENTIAL THAT THE WIRING CONNECTIONS TO THE GENERATOR ARE NOT REMOVED WHILE THE ENGINE IS RUNNING, AS THIS WILL RESULT IN DAMAGE TO THE REGULATOR OR PERSONAL INJURY.

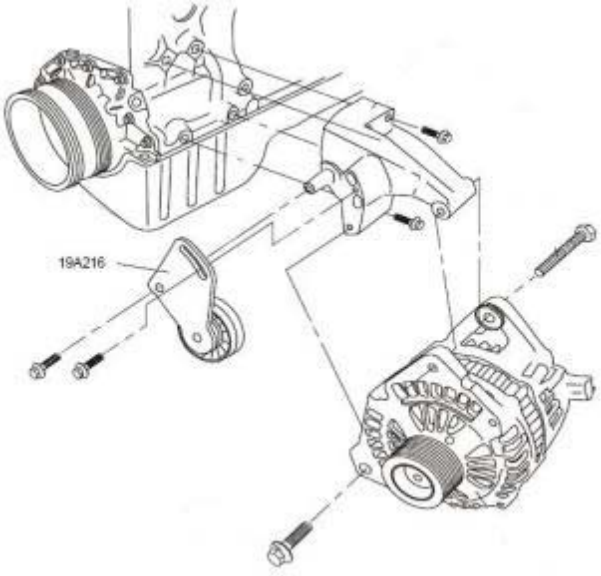
WARNING: KEEP BATTERIES OUT OF THE REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION. IN CASE OF ACID CONTACT WITH THE SKIN OR EYES, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES AND GET PROMPT MEDICAL ATTENTION. IF ACID IS SWALLOWED, CALL A PHYSICIAN IMMEDIATELY. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

NOTE: Battery posts and cable clamps must be clean and tight for accurate meter indications.

CAUTION: Always remove the negative cable first to prevent possible arcing possibly damaging other electrical components.

TSG-416 CHARGING SYSTEM

GENERAL INFORMATION



Description

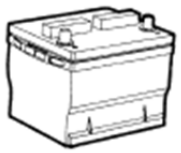
WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

The charging system consists of a generator, voltage regulator and battery. A serpentine belt drives the generator from the crankshaft pulley -- refer to Section 5 for information on the drive belt.

The generator produces alternating current which is subsequently converted to direct current
The charging rate is adjusted automatically by the built-in regulator to provide sufficient electric current to keep the battery fully charged under normal operating conditions.

Battery power

The battery is a 12 volt DC source connected in a negative ground system. There are three main functions of the battery:



- To supply power to the starter and ignition system so the engine can be cranked and started.
- To supply extra power required when the equipment load requirements exceed the supply from the charging system.
- To act as a voltage stabilizer by smoothing out or reducing temporary high voltages within the electrical system.

Operation

With the ignition on, voltage is applied to the voltage regulator. This turns the regulator on, allowing current to flow from the battery to the generator field coil.

When the engine is started, the generator begins to generate alternating current (AC) which is internally converted to direct current (DC). This current is then supplied to the equipment electrical system through the B+ terminal of the generator.

Once the generator begins generating current, a voltage signal is taken from the generator stator and fed back to the regulator. This voltage feedback signal (typically half the battery voltage) is used to turn off the warning indicator.

With the system functioning normally, the generator output current is determined and compared to a set voltage internal to the regulator, and the regulator controls the generator field current to maintain the correct generator output.

The set voltage varies with temperature and typically is higher in cold temperatures and lower in warm temperatures. This allows for better battery recharge in the winter and reduces the chance of overcharging in the summer.

TSG-416 CHARGING SYSTEM

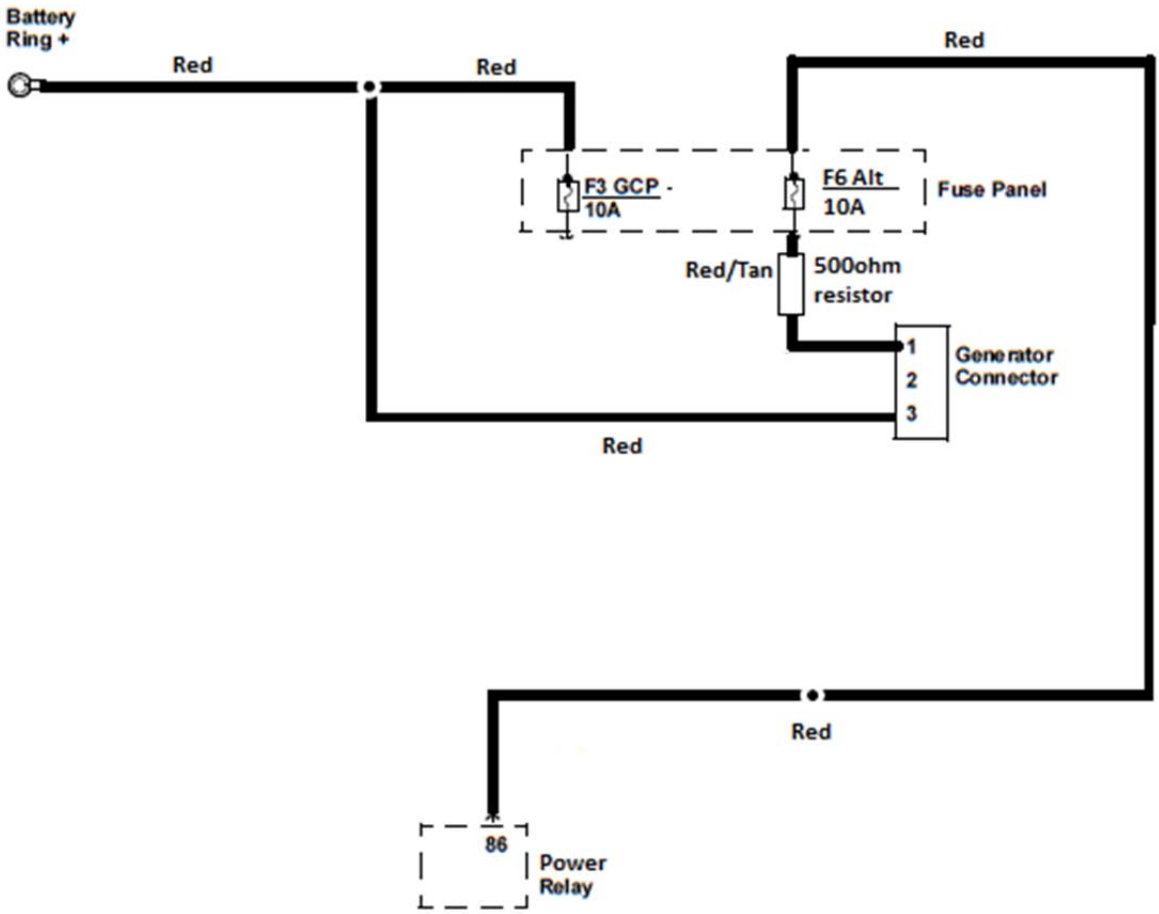
Wiring Diagram

Revision Level

The following wiring schematics are taken from the wiring diagram labeled below:

Title: EDI / FORD 1.6L W/GCP 2010 DEPR		
Size: D	Number: 2122200	Rev: B
Date: 7/1/2010	Drawn By: J. SUTTON	
Filename: 2122200b.sch	Sheet 1 of 1	

Charging System



DIAGNOSIS AND TESTING

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

NOTE: When the battery is disconnected and connected, some abnormal symptoms may occur while the GCP relearns its adaptive strategy. The engine may need to run to relearn its strategy.

Preliminary Checks

Before beginning test procedures, check battery cables and generator wiring (especially grounds) for clean, tight connections. Wires and connectors should not be damaged or corroded.

Perform the following checks before any testing:

- Loose or corroded connections at battery, grounded starter motor cutout relay or engine.
- Inspect all connectors for loose or damaged pins, wires, etc.
- Make sure the batteries are at 75% state of charge (SOC) or higher. This represents an open circuit voltage (OCV) of 12.4 volts. Batteries with an OCV of 12 volts or less are either completely discharged or have a dead cell.
- Check the generator drive belt tension. This will cause low generator output.
- Check any light or indicator lamp filaments that are suspected of being open (burned out). This is done to avoid unnecessary extensive circuit checks.
- If a fuse is blown, locate the cause of the overload condition and repair it. The common procedure is as follows: isolate sections of the circuit, by disconnecting connectors, and measure the resistance to ground to find the circuit that is shorted to ground. Then locate the damaged spot in the wire or connector and repair.
- Excessive battery drain due to lamps left on, damaged or misadjusted switch, accessories left on, etc.

Warning Indicator Check

Check the operation of the charging system warning indicator as follows:

- Ignition OFF = Indicator should be OFF.
- Ignition ON, Engine OFF = Indicator should be ON.
- Ignition ON, Engine ON = Indicator should be OFF.

Symptom Chart

CONDITION	POSSIBLE SOURCE	ACTION
Dead battery. **Battery will not stay charged.** **Slow crank.** **Low battery voltage.** **No generator output.**	• Key-off battery drain. • Open/voltage drop in B+ circuit. • Open voltage drop in A circuit. • Open/high resistance in I circuit. • Voltage regulator. • Generator.	Repair as necessary
Indicator lamp on with engine running.	• Open "A" circuit. • Shorted "I" circuit. • Open/high resistance in "S" circuit. • Voltage regulator. • Generator.	Repair as necessary
Indicator lamp flickers or intermittent.	• Loose connection to generator, voltage regulator or battery. • Loose fuse or poor connection in "A" circuit. • Loose brush holder screw. • Voltage regulator. • Generator.	Repair as necessary
Battery over charging (battery voltage greater than 15.5 volts).	• Voltage drop in "A" circuit. • Voltage drop in "I" circuit • Poor ground. • Voltage regulator. • Generator.	Repair as necessary
Indicator lamp off, key on, engine not running.	• Open/high resistance in "I" circuit. • Burned out bulb • Poor ground • "S" circuit shorted to B+ • Voltage regulator. • Generator.	Repair as necessary
Generator noisy.	• Accessory drive belt. • Accessory brackets. • Bent generator pulley • Generator. • Other components.	Repair as necessary
Indicator lamp on, key off.	• Lamp circuit shorted to B+. • Improper lamp circuit wiring.	Repair as necessary

Battery Drain Test

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

A defective component or wiring defect may be causing a small current drain that is less than the fuse rating for the circuit so the fuse does not open. Perform the following to determine if an excessive drain is occurring:

NOTE: Batteries should be fully charged for the following test.

WARNING: DO NOT ATTEMPT THIS TEST ON A LEAD-ACID BATTERY THAT HAS RECENTLY BEEN RECHARGED. EXPLOSIVE GASES MAY CAUSE PERSONAL INJURY. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

CAUTION: To prevent damage to the meter, do not crank engine or operate accessories that draw more than 10A.

1. Allow the engine to sit with the ignition off for at least 40 minutes to allow the GCP to power down.
2. Connect a fused (10A) jumper wire between the negative battery cable and post to prevent the GCP from resetting and to catch capacitive drains.
3. Disconnect the negative battery cable without breaking the connection of the jumper wire.

NOTE: It is very important that continuity between the negative battery cable and post is not broken. If it is, the entire procedure must be repeated so the GCP can power down again.

4. Connect an ammeter between the negative battery cable and post. The meter should have a 10 amp capability.

NOTE: If after this next step, the meter settings need to be switched or the test leads need to be moved to another jack, the jumper wire must be reinstalled to avoid breaking continuity.

5. Remove the jumper wire and note the amperage draw:
   - There should not be any more than 50 mA (0.050 amp) draw.
   - If excessive, remove fuses one at a time until the circuit with the excessive draw is located.
   - Use the wiring diagram to locate any circuits that do not pass through the fuse box.
   - Disconnect the generator connections to check for an internal short causing an excessive draw.

Battery Load Test

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Disconnect both battery terminal cables. Check the battery visually.
2. Examine the hydrometer eye (if no eye go to next step).
   - Eye shows green - go to step 4.
   - Eye shows dark - recharge, then go to step 4.
   - Eye shows yellow - replace battery.
3. Apply a 300 amp load for 15 seconds. Turn off load and wait one minute.
   - If 12.4 volts or more - go to step 4.
   - If less than 12.4 volts - recharge, then repeat step
4. Apply a test load equal to 50% of the battery CCA rating at - 17.8° C (0°F). After 15 seconds, **with the load still applied**, measure and record terminal voltage _____. Turn the load OFF.
5. Estimate the battery temperature. If measured voltage does not meet or exceed the value shown in the following table, replace the battery.

Temp. °C	21.1°	10°	-1.1°	-9.4°	-17.8°
Temp. °F	70°	50°	30°	15°	0°
Min. Volts	9.6	9.4	9.1	8.8	8.5

6. Clean all cable ends and terminals of the battery with a wire brush.

TSG-416 CHARGING SYSTEM

Generator Output Test

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

CAUTION: To prevent damage to the generator, do not make jumper wire connections except as directed.

CAUTION: Do not allow any metal object to come in contact with the housing and the internal diode cooling fins with the ignition on or off. A short circuit may result and burn out the diodes.

In order to check the generator, the use of rotunda Starting and charging System Tester 078-00005 (VAT-40) or equivalent, is recommended.

NOTE: Refer to the test equipment user's manual for complete directions on examining the charging system.

NOTE: Turn off all lamps and accessories.

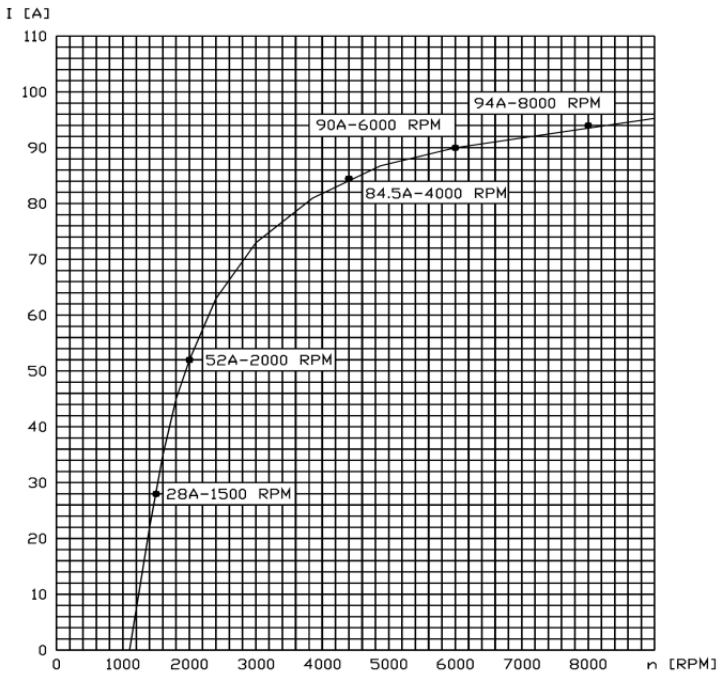
1. Switch the tester to ammeter function.
2. Connect the positive and negative leads of the tester to the battery.
3. Connect current probe to generator B+ terminal to measure generator output.
4. With the engine running at 2000 rpm, adjust the VAT-40 or equivalent load bank to determine the output of the generator. Generator output should be greater than values given in the graph below.

Generator Voltage Test

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

1. Switch the tester to the voltmeter function.
2. Connect the positive lead to the generator A terminal connector and the negative lead to ground.
3. Turn off all electrical accessories.
4. With the engine running at 2000 rpm, check the generator voltage.
5. Voltage should be between 13.0-15.5 volts.

GENERATOR AMPS VS RPM CHART



GENERAL SERVICE PROCEDURES

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

Battery Cleaning and Inspection

Keeping the battery top clean and dry reduces the need for service and extends battery life. Also, make certain the cable clamps are tightly fastened to the battery posts. If corrosion is found, disconnect the cables and clean clamps and posts with a wire brush. Neutralize the corrosion with a solution of baking soda and water. After installing cables, apply a small quantity of Premium Long-Life Grease XG-1-C or -K or equivalent grease meeting Ford specification ESA-M1C75-B to each battery post to help prevent corrosion.

Battery Tools

Anyone working with a battery needs the proper tools. Using the right tools will prevent damage to the battery, battery cables and battery hold down clamp.
Tools and equipment manufactured for servicing batteries have parts insulated to help prevent arcing should the tool be dropped or placed accidentally between a terminal and some other contact surface.

Clamp Puller

Use a clamp puller to remove a cable clamp from the battery terminal. With the jaws gripping the underside of the cable clamp, pull the clamp up by means of pressure exerted against the top of the battery terminal. Proper use of this tool avoids the damaging lateral or twisting forces that result when using a pry bar or pliers.

Battery Clamp Spreader

The spreader is used to expand the cable clamp after it has been removed from the terminal and the clamp bolt has been loosened. The cable clamp can then be easily placed in its correct position completely on the terminal.

Terminal Cleaning Brush

The terminal cleaning brush is designed with units to clean both tapered battery terminal and the mating surface of the cable clamp.

WARNING: GRIPPING THE END WALLS ON THE PLASTIC-CASED BATTERY COULD CAUSE ELECTROLYTE TO SPEW FROM SOME OF THE CELLS, RESULTING IN PERSONAL INJURY AND POSSIBLY CAUSE DAMAGE TO SOME OF THE INTERNAL COMPONENTS.

Use a suitable battery carrier for lifting and transporting the battery. The illustration shows a clamp-type carrier used to grip the sidewalls of the container just below the lip of the cover. The carrier is used on the sidewalls, rather than the end walls, since the sidewalls have additional strength from the inner cell partitions. This is particularly important with the plastic-cased battery which has end walls that are flexible.

Battery Charging

WARNING: REFER TO CAUTIONS & WARNINGS AT THE BEGINNING OF THIS SECTION.

NOTE: If excessive gassing or electrolyte spewing occurs during the charge, discontinue charging. The battery has reached serviceable charge. If the battery will not accept at least 5A after 20 minutes of charging, replace the battery.

WARNING: WEAR SAFETY GLASSES. BATTERY CHARGING CAN BE DANGEROUS. WHILE BEING CHARGED, THE BATTERY PRODUCES A POTENTIALLY EXPLOSIVE MIXTURE OF HYDROGEN AND OXYGEN GASSES. KEEP SPARKS, FLAMES AND LIGHTED CIGARETTES AWAY FROM BATTERIES. IN CASE OF ACID CONTACT WITH SKIN, EYES OR CLOTHING, FLUSH IMMEDIATELY WITH LARGE AMOUNTS OF WATER. GET MEDICAL ATTENTION.

Inspect and service any of the following pre-existing conditions before recharging a discharged battery -- Refer to “Preliminary Checks” on page 5 of this section.

Cold batteries will not readily accept a charge. Therefore, batteries should be allowed to warm up to approximately 5°C (41°F) before charging. This may require four to eight hours at room temperature depending on the initial temperature and battery size.

A battery which has been completely discharged may be slow to accept a charge initially, and in some cases may not accept charge at the normal charger setting. When batteries are in this condition, charging can be started by use of the dead battery switch on chargers so equipped.

To determine whether a battery is accepting a charge, follow charger manufacturer’s instructions for use of dead battery switch. If switch is the spring-loaded type, it should be held in the ON position for up to three minutes.

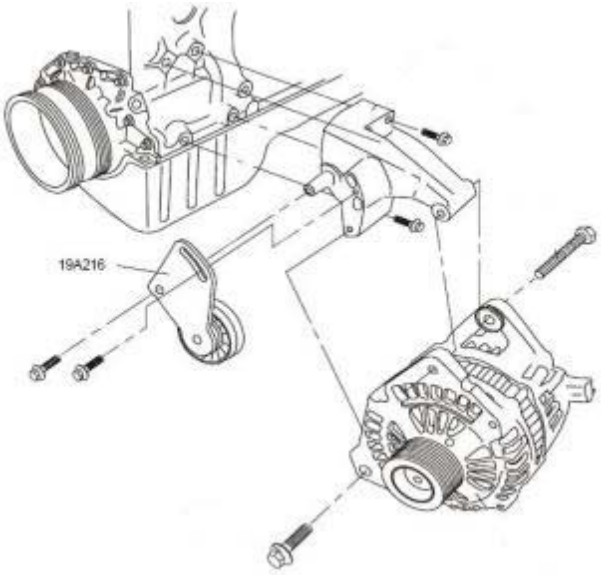
After releasing switch and with charger still on, measure battery voltage. If it shows 12 volts or higher, the battery is accepting a charge and is capable of being recharged. However, it may require up to two hours of charging with batteries colder than 5°C (41°F) before charging rate is high enough to show on the charger ammeter. It has been found that all non-damaged batteries can be charged by this procedure. If a battery cannot be charged by this procedure, it should be replaced.

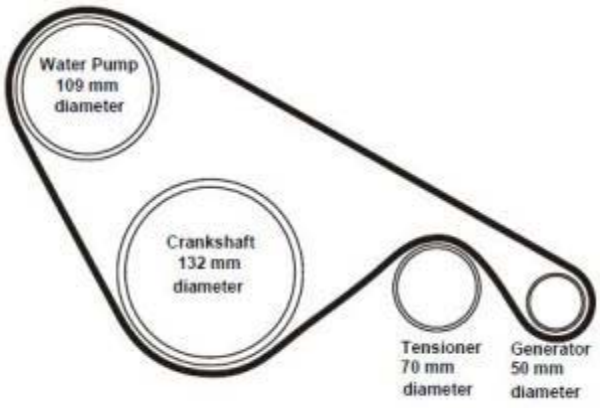
A rapid recharge procedure has been developed for recharging batteries that only need a quick recharge. This can be due to battery in-service no-start battery failures (engine will not crank due to low battery state of charge) or battery discharged due to key-off loads.

The battery can be rapidly recharged by using either of the following methods.

- Perform a two-hour charge using 20A constant current (manual setting on charger).
- Perform a two-hour charge using a constant potential (automatic setting on charger).

REMOVAL AND INSTALLATION
Generator – Replacement

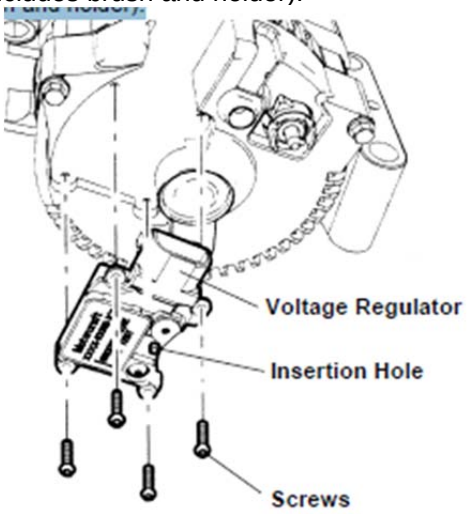




1. Disconnect battery negative cable -- Refer to “Battery Cleaning and Inspection” on page 9 of this section.
2. Remove or disconnect any component to allow access and removal of generator.
3. Remove drive belt -- refer to cooling system section.
4. Remove 2 bolts and position the generator aside.
5. Disconnect electrical connector.
6. Remove generator.
7. Reverse procedure to install:
    - Tighten generator bolts to 25 Nm (18 lb-ft).
    - Tighten B+ terminal to 8 Nm (71 lb-in).

Voltage Regulator – Replacement

1. Remove the generator -- Refer to “Generator - Replacement” in this section.
2. Remove 4 screws and voltage regulator (includes brush and holder).

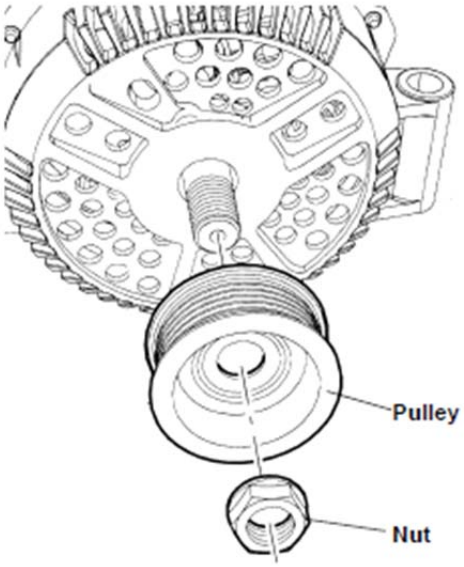


3. Reverse procedure to install:
    - Insert a wire into the insertion hole to hold the brushes during assembly. Remove wire when done.
    - Tighten screws to 3 Nm (27 lb-in).

Generator Pulley - Replacement

1. Remove generator assembly -- Refer to "Generator - Replacement" of this section.

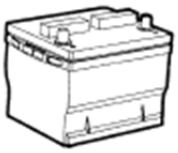
2. Remove nut.



3. Remove pulley.

4. Reverse procedure to install:
   - Tighten nut to 109 Nm (80 lb-ft).

Battery - Removal



WARNING: WHEN LIFTING PLASTIC CASED BATTERY, EXCESSIVE PRESSURE ON THE END WALLS COULD CAUSE ACID TO SPEW THROUGH THE VENT CAPS, RESULTING IN PERSONAL INJURY, DAMAGE TO THE EQUIPMENT OR BATTERY. LIFT WITH A BATTERY CARRIER OR WITH YOUR HANDS ON OPPOSITE CORNERS.

WARNING: KEEP OUT OF REACH OF CHILDREN. BATTERIES CONTAIN SULFURIC ACID. AVOID CONTACT WITH SKIN, EYES, OR CLOTHING. ALSO, SHIELD YOUR EYES WHEN WORKING NEAR THE BATTERY TO PROTECT AGAINST POSSIBLE SPLASHING OF THE ACID SOLUTION.
IN CASE OF ACID CONTACT WITH SKIN OR EYES, FLUSH IMMEDIATELY WITH WATER FOR A MINIMUM OF 15 MINUTES AND GET PROMPT MEDICAL ATTENTION. IF ACID IS SWALLOWED, DRINK LARGE QUANTITIES OF MILK OR WATER, FOLLOWED BY MILK OF MAGNESIA, A BEATEN EGG, OR VEGETABLE OIL. CALL A PHYSICIAN IMMEDIATELY.

CAUTION: Care should be taken when removing or replacing the cable clamp bolts so that the battery terminal is not subjected to any excessive lateral or twisting forces. Such forces could cause major damage to the internal components of the battery, and leakage at the terminals.

1. Remove battery cables from battery terminals (battery ground cable first).
2. Remove battery hold down components.

CAUTION: When lifting a plastic-cased battery, excessive pressure on the end walls could cause acid to spew through the vent caps, resulting in personal injury, damage to the equipment or battery. Lift with a battery carrier or with your hands on opposite corners.

3. Remove battery from equipment.

Battery - Installation

1. Clean cable terminals and battery hold down clamp with a wire brush. Replace all cables or parts that are worn or frayed.
2. Clean battery tray with a wire brush and scraper.
3. Place battery in battery tray with positive and negative cables in same position as when removed.
4. Assemble and tighten battery hold down clamp so battery is secure. Do not tighten excessively.
5. Secure cables to proper terminals. Tighten to 6 Nm (53 lb-in). Apply petroleum jelly to terminals.

Ford Motor Company strongly recommends that lead acid batteries be returned to an authorized recycling facility for disposal.

TSG-416 CHARGING SYSTEM

SPECIFICATIONS

GENERAL SPECIFICATIONS	
Generator Output	90 Amp at 600 RPM; 2.72:1 drive ratio
Battery	Motorcraft 12 volt 750 CCA
Battery charging voltage	13 – 15.5 volts

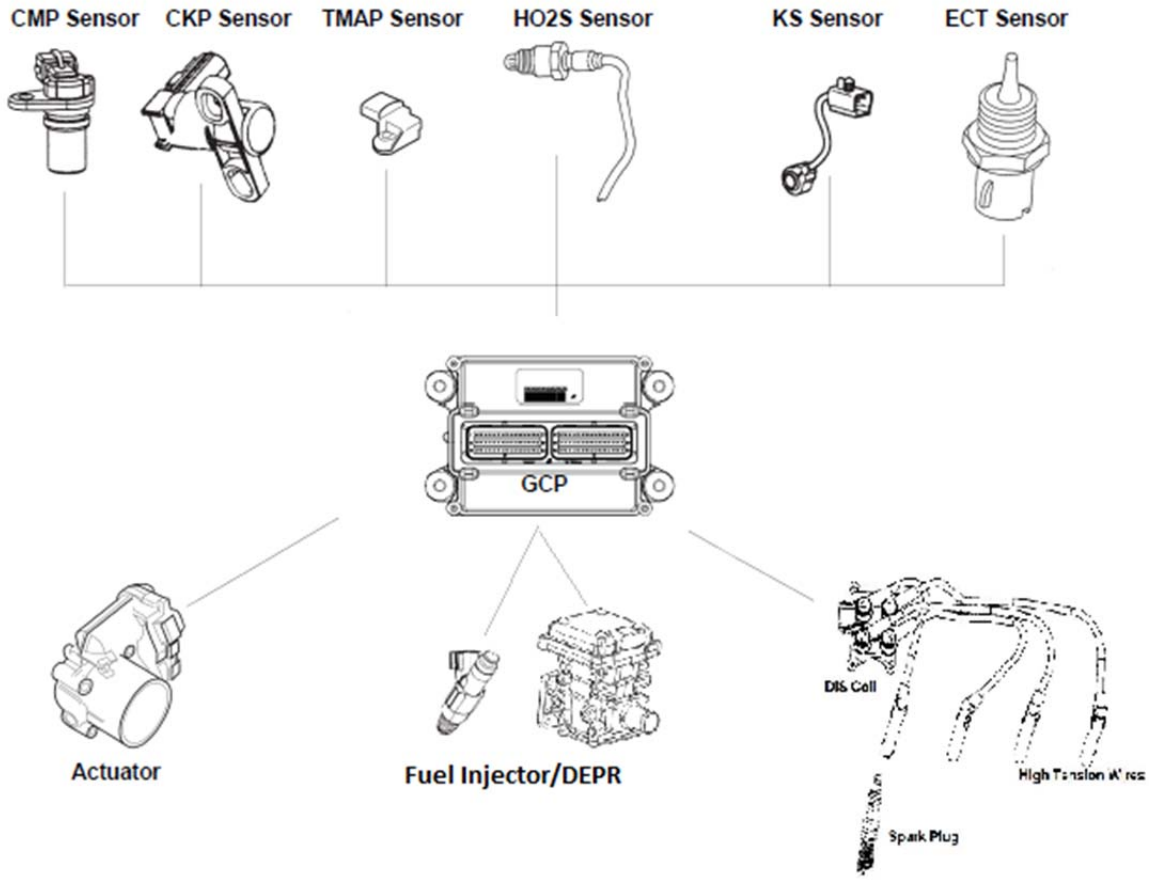
TORQUE SPECIFICATIONS			
Description	**Nm**	**Lb-ft**	**Lb-in**
Generator Mounting bolts	25	18	---
Regulator attachment screws	3	---	27
Battery cable nuts	6	---	53
Generator pulley nut	109	80	---
Generator wiring nuts	8	---	71

TSG-416 Engine Controls

INDEX

Subject	Page
General Information	**08 – 2**
GCP and Sensors	08 – 2
Fuel System Components	08 – 8
Coil-on-plug ignition	08 – 10
Open Loop and Closed Loop Operation	08 – 11
Adaptive Learn	08 – 11
GCP Service Precautions	08 – 11
Use of Circuit Testing Tools	08 – 11
Electrostatic Discharge Damage	08 – 11
Diagrams and schematics	08 – 12
Engine component locator view	08 – 24
Diagnosis and Testing	
Diagnostic approach	08 – 25
GCP diagnostic overview	08 – 25
On-board diagnostics – GCP	08 – 25
Engine control module (GCP) Limp Home Mode Strategy	08 – 25
Intermittent MIL	08 – 26
Malfunction indicator light (MIL) DTC Retrieval procedure	08 – 27
Diagnosis and using a personal computer	08 – 27
Visual Inspection	08 – 36
Intermittent problems	08 – 36
Symptom charts	08 – 37
Engine Control Module (GCP) – Diagnostic Trouble Codes	08 – 40
Removal and Installation	
Camshaft Position (CMP) Sensor – Replacement	08 – 41
Crankshaft Position (CKP) Sensor – Removal	08 – 41
Crankshaft Position (CKP) Sensor – Installation	08 – 42
Engine Coolant Temperature (ECT) Sensor – Replacement	08 – 43
Heat Oxygen Sensor (HO2S) – Replacement	08 – 43
Knock Sensor (KS) – Replacement	08 – 44
Temperature Manifold Absolute Pressure (TMAP) Sensor – Replacement	08 – 44
Actuator/Throttle Position (TP) Sensor – Replacement	08 – 45

GENERAL INFORMATION
GCP and Sensors



Engine Control Module (GCP)

The Engine Control Module (GCP) has the following features:

- Programmable four speed electronic governing, throttle-by-wire or variable speed control governing.
- Programmable emergency warning/shut-down feature for high water temperature, low oil pressure, etc.
- Starter lockout.
- Auto crank
- Programmable overspeed protection
- Automatic altitude compensation.
- Sequential port fuel injection (gasoline) with pressure regulator to precisely control fuel delivery.
- Dry fuel lockout controlled by the GCP produces a reliable transition when switching fuels.
- Certified closed loop dry fuel control.
- Configurable inputs available based on customer requirements.
- Configurable outputs available based on ECT, RPM or MAP signals and customer requirements.
- Diagnostic software allows viewing of historical and active faults with on-demand diagnostics to assist technicians and reduce equipment downtime.

The Engine Control Module (GCP) engine control system is a complete engine control system for Ford industrial engines running on gasoline, propane or natural gas. Each module can be set up to run an engine on any two of the three fuels in certified closed loop control, with virtually transparent on-the-fly fuel switching.

Each module can also be set up to run on a variety of electronic governing:

- It can be programmed to provide up to four specific speeds with use of a matching toggle switch
- It can be programmed to provide an infinite variety of speeds (with customer-specified minimum and maximum) based on a variable signal input.
- It can be an electronic replacement for a throttle cable with maximum speed governing (throttle-bywire).

- Or it can switch between throttle-by-wire and a second fixed or variable input based on a neutral/ parking brake signal.

With the GCP system, a laptop and a communications cable, diagnosis becomes simpler. The technician can either view engine data with a real time graphing program, or store that data into a numeric data file.

Every time a fault is set, the laptop will give you detailed information about the fault, including:

- when it happened
- if the fault still exists
- a list of essential engine data from the time of the fault.

It can also display a 10 second graph of critical engine data, from 8 seconds before the fault occurred to two seconds after.

With many OEMs using control modules to control their machinery, the GCP has the ability to communicate engine data to and receive commands from other control modules through a Controller Area Network (CAN) link, with messages written in the J1939 protocol.

This allows large amounts of data to move throughout the machine through only two wires, and can be used to run some module based gauge packages.

The GCP also carries auxiliary features that can be programmed to control OEM devices, allowing the OEM to eliminate components from their machinery.

The GCP is also equipped with multiple safety and protection devices that protect the user and engine from hazards such as:

- over speed
- over temperature
- over voltage
- low oil pressure
- unauthorized tampering
- over cranking starter motor.

The GCP controls the following:

- Fuel metering system
- Ignition timing
- On-board diagnostics for engine functions

The GCP constantly observes the information from various sensors. The GCP controls the systems that affect engine performance. The GCP performs the diagnostic function of the system. It can recognize operational problems, alert the operator through the Malfunction Indicator Lamp (MIL), and store diagnostic trouble codes (DTC's). DTC's identify the problem areas to aid the technician in making repairs.

The GCP supplies either 5 or 12 volts to power various sensors or switches. The power is supplied through resistances in the GCP which are so high in value that a test light will not light when connected to the circuit. In some cases, even an ordinary shop voltmeter will not give an accurate reading because its resistance is too low. Therefore, a digital voltmeter with at least 10 megohms input impedance is required to ensure accurate voltage readings. The GCP controls output circuits such as the fuel injectors, electronic governor, etc., by controlling the ground or the power feed circuit through transistors or other solid state devices.

The GCP is designed to maintain exhaust emission levels to government mandated standards while providing excellent operation and fuel efficiency. The GCP monitors numerous engine functions via electronic sensors such as the throttle position (TP) sensor and the heated oxygen sensor (HO2S).

GCP Inputs (operating conditions read)

- Engine Coolant Temperature
- Crankshaft Position
- Exhaust Oxygen Content
- Manifold Absolute Pressure
- Battery Voltage
- Throttle Position / Electronic Actuator
- Fuel Pump Voltage
- Intake Air Temperature
- Camshaft Position

GCP Outputs (systems controlled)

- Fuel control (Injectors/DEPR)
- Electronic Throttle Control
- Electric Fuel Pump (gasoline)
- Diagnostics - Malfunction Indicator Lamp (check engine lamp)
- Diagnostics - Data Link Connector (DLC)
- Variable valve timing (VVT)

Crankshaft Position (CKP) Sensor

The Crankshaft Position (CKP) Sensor provides a signal used by the Engine Control Module (GCP) to calculate the ignition sequence. The sensor initiates the reference pulses which the GCP uses to calculate RPM and crankshaft position.

Camshaft Position (CMP) Sensor

The Camshaft Position (CMP) Sensor uses a variable reluctor sensor to detect camshaft position. The CMP signal is created as piston #1 is a pre-determined number of degrees after top dead center on the power stroke.

The Camshaft Position (CMP) Sensor sends a CMP signal to the GCP. The GCP uses this signal as a “sync pulse” to trigger the injectors in the proper sequence.
The GCP uses the CMP signal to indicate the position of the #1 piston during its power stroke. The CMP uses a Hall Effect sensor to measure piston position. This allows the GCP to calculate true sequential fuel injection (SFI) mode of operation. If the GCP detects an incorrect CMP signal while the engine is running, DTC 341 will set (CAM sync noice).

If the CMP signal is lost while the engine is running, the fuel injection system will shift to a calculated sequential fuel injection mode based on the last fuel injection pulse, and the engine will continue to run. As long as the fault (DTC 342, CAM loss) is present, the engine can be restarted. It will run in the previously established injection sequence.

Engine Coolant Temperature (ECT) Sensor

The Engine Coolant Temperature (ECT) Sensor is a thermistor (a resistor which changes value based on temperature) mounted in the engine coolant stream. Low coolant temperature produces a high resistance of 100,000 ohms at -40°C (-40°F). High temperature causes a low resistance of 70 ohms at 130°C (266°F).
The GCP supplies a 5 volt signal to the ECT sensor through resistors in the GCP and measures the voltage. The signal voltage will be high when the engine is cold and low when the engine is hot. By measuring the voltage, the GCP calculates the engine coolant temperature. Engine coolant temperature affects most of the systems that the GCP controls.

After engine start-up, the temperature should rise steadily to about 85°C (185°F). It then stabilizes when the thermostat opens. If the engine has not been run for several hours (overnight), the engine coolant temperature and intake air temperature displays should be close to each other. A fault in the engine coolant sensor circuit will set a DTC 117 or DTC 118 (Low/High Voltage.

Heated Oxygen Sensor (HO2S)

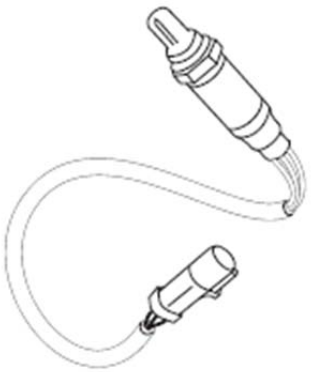
The Heated Oxygen Sensor (HO2S) is mounted in the exhaust stream where it can monitor the oxygen content of the exhaust gas. The oxygen present in the exhaust gas reacts with the sensor to produce a voltage output. This voltage should constantly fluctuate from approximately 100mV to 900 mV, when the engine is running in closed loop fuel control.

The Heated Oxygen Sensor (HO2S) voltage can be monitored on an IBM PC compatible computer with diagnostic software. By monitoring the voltage output of the oxygen sensor, the GCP calculates the pulse width command for the injectors to produce the proper combustion chamber mixture.

The 4-wire HO2S indicates whether the air/fuel ratio is rich or lean with respect to stoichiometry. The signal from this sensor contains valid air/fuel ratio information only when the sensor element has reached its normal operating temperature. The 4-wire HO2S also has an isolated case ground which goes to Signal Return (SIGRTN) either in the processor (as a dedicated HO2S ground) or as a jumper to SIGRTN in the wiring harness.

Low HO2S voltage indicates a lean mixture which will result in a rich command to compensate.

High HO2S voltage indicates a rich mixture which will result in a lean command to compensate.



Specifications

- Accuracy of measurement: ±1.5%
- Operating Temp. Range: 350°C to 850°C (sensor tip)
- Sensor Response Time: 300-1500 msec.
- Heater Current Draw: 1 A steady state
- Voltage Output:
    - 0 - 450 mV (lean exhaust gas)
    - 450 - 1000 mV (rich exhaust gas)

Temperature Manifold Absolute Pressure (TMAP) Sensor

The Temperature Manifold Absolute Pressure (TMAP) Sensor responds to changes in intake manifold pressure (vacuum). The TMAP sensor signal voltage to the GCP varies from below 2 volts at idle (high vacuum) to above 4 volts with the ignition ON, engine not running or at wide-open throttle (low vacuum).

The TMAP sensor consists of a pressure sensing element (capacitor) and signal conditioning electronics. The capacitor has a vacuum/pressure reference which results in one surface (diaphragm) of the capacitor being partially deflected. Further changes in pressure produce corresponding changes in the deflection of the diaphragm and therefore a change in capacitance. This capacitance change is converted to a frequency by the conditioning electronics.

The TMAP sensor is used to determine the following:

- Engine vacuum level for engine control purposes.
- Barometric pressure (BARO).

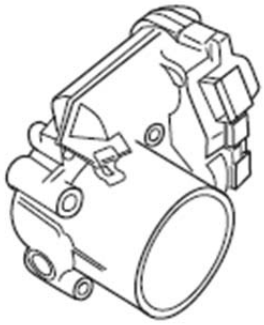
Specifications:

- Range of Measurement: 1.7 - 15.2 psi.
- Measurement Accuracy: ± 0.2 psi
- Sensor Response Time: 3-15 msec.
- Resolution: 0.02 psi

Present design: Silicon Capacitive Absolute Pressure (SCAP) sensor with a maximum operating temperature of 100°C. The output is a 50% duty cycle wave form whose frequency is proportional to the pressure input.

Throttle Position (TP) Sensor / Electronic Actuator

The Throttle Position (TP) Sensor is a dual track rotary potentiometer that uses a variable resistive element which is packaged inside a plastic housing. The resistive element varies linearly and is directly proportional to the throttle plate angle. The GCP applies reference voltage and ground to the sensor and monitors the sensor's ratio metric output voltage to determine precise throttle position. The electronic actuator has two TP outputs that the GCP monitors.



The Electronic Actuator consists of a throttle body, an electronically-actuated throttle plate, and a built-in throttle position (TP) Sensor. The Electronic Actuator also acts as an idle air control (IAC) valve. Changes in engine load are detected by the GCP by comparing manifold absolute pressure (TMAP) with throttle position. When the GCP detects a change in engine load, it can adjust idle speed by changing the PWM signal to the actuator.

As the throttle valve opens, the output increases so that at wide open throttle (WOT), the output voltage should be above 4 volts.

The GCP calculates fuel delivery based on throttle valve angle (operator demand). A hard failure in the TP sensor 5 volt reference or signal circuits for greater than 2 consecutive seconds will set a DTC 123 or DTC 223. A hard failure with the TP sensor ground circuit for more than two consecutive seconds may set DTC 222. If any (TP) DTC is set the GCP will shut down the engine immediately.

Specifications:

- Range of Measurement: 0-85° (angular)
- Measurement Accuracy: ±2% of VREF
- Resolution: 0.5° max.

Fuel System Components - Gasoline

The fuel metering system is made up of the following parts:

- The fuel injectors (gasoline)
- The fuel rail (gasoline)
- The fuel filter (gasoline)
- The GCP
- The Crankshaft Position (CKP) Sensor
- The Camshaft Position (CMP) Sensor
- The fuel pump (gasoline)
- The fuel pump relay (gasoline)
- The Direct Electronic Pressure Regulator (Gaseous Fuels)
- The Fuel Lock Off Solenoid (Gaseous Fuels)
- The Mixer (Gaseous Fuels)
- The Vapor Regulator (LPG/CNG)
- Heated Oxygen (HO2S) Sensor
- Temp/Manifold Absolute Pressure (TMAP) Sensor

The basic function of the air/fuel metering system is to control the air/fuel delivery to the engine. Fuel is delivered to the engine by individual fuel injectors mounted in the intake manifold near each intake valve.

The fuel metering system starts with the fuel in the fuel tank. The fuel is drawn up to the fuel pump through a pre-filter. The electric fuel pump then delivers the fuel to the fuel rail through an in-line fuel filter. The pump is designed to provide fuel at a pressure above the pressure needed by the injectors. A fuel pressure regulator in the fuel filter assembly keeps fuel available to the fuel injectors at a constant pressure of 45psig. A return line delivers unused fuel back to the tank.

The main control sensor is the heated oxygen sensor (HO2S) located in the exhaust system. The HO2S tells the GCP how much oxygen is in the exhaust gas. The GCP changes the air/fuel ratio to the engine by controlling the amount of time that the fuel injector is “ON”. The best mixture to minimize exhaust emissions is 14.7 parts of air to 1 part of gasoline by weight, which provides the most efficient combustion. Because of the constant measuring and adjusting of the air/fuel ratio, the fuel injection system is called a “closed loop” system.

The GCP monitors signals from several sensors in order to determine the fuel needs of the engine. Fuel is delivered under one of several conditions called “modes”. All modes are controlled by the GCP. Refer to “Open Loop and Closed Loop Operation” for more information.

Fuel Injector

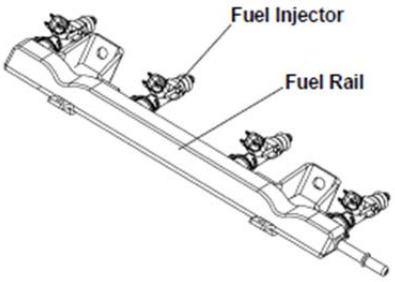
The Electronic Fuel Injection (EFI) fuel injector is a solenoid operated device controlled by the GCP. The GCP energizes the solenoid, which opens a valve to allow fuel delivery.

The fuel is injected under pressure in a conical spray pattern at the opening of the intake valve. Excess fuel not used by the injectors passes through the fuel pressure regulator before being returned to the fuel tank.

A fuel injector which is stuck partly open will cause a loss of fuel pressure after the engine is shut down, causing long crank times.

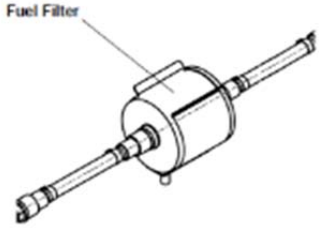
Fuel Rail

The fuel rail is mounted to the top of the engine and distributes fuel to the individual injectors. Fuel is delivered to the fuel inlet tube of the fuel rail by the fuel lines.



Fuel Filter

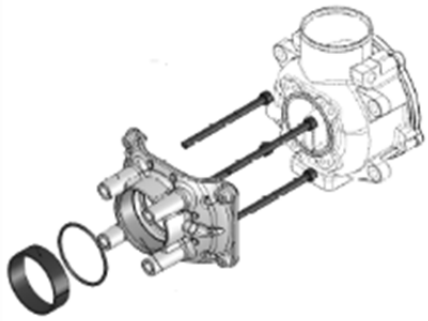
The fuel filter is an inline filter assembly. Refer to Section 4 for information on relieving fuel pressure, disconnecting fuel lines and fuel filter replacement.



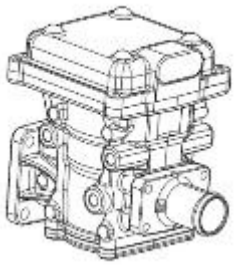
Fuel Pump Electrical Circuit
When the key is first turned “ON”, the GCP energizes the fuel pump relay for two seconds to build up the fuel pressure quickly. If the engine is not started within two seconds, the GCP shuts the fuel pump off and waits until the engine is cranked. When the engine is cranked and crankshaft position signal has been detected by the GCP, the GCP supplies 12 volts to the fuel pump relay to energize the electric fuel pump.

An inoperative fuel pump will cause a “no-start” condition. A fuel pump which does not provide enough pressure will result in poor performance.

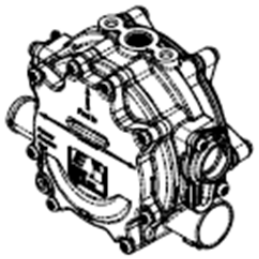
Mixer (Gaseous Fuels)
The Mixer allows air and fuel to mix together before entering the engine. Based on pressure differentials the diaphragm in the mixer will actuate allowing the proper amount of air and fuel to mixer together. This pressure differential is based on the vacuum in the intake manifold of the engine which is directly related to load.



DEPR (Direct Electronic Pressure Regulator)
The DEPR controls the fuel trim to the engine on dry fuels based on inputs to the GCP (HO2 sensor, MAP sensor, crank and cam sensors). Nominal pressure input to the DEPR is ~ 11” WC and outputs ~ 4 – 5” WC. It is mounted directly to the mixer.



Vapor Regulator
The vapor regulator is used with LPG and CNG fuels. It converts LPG from a liquid state to a gaseous state. Nominal pressure output is ~11” of WC to the DEPR.



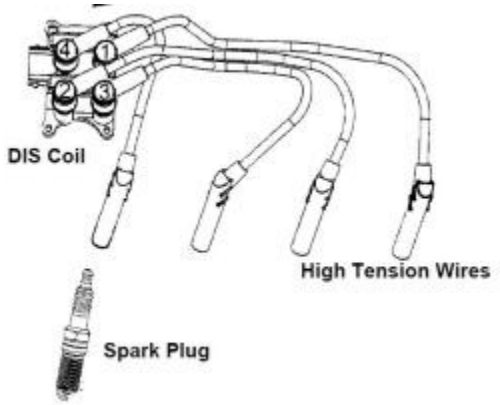
Coolant is run through the DEPR to prevent freezing of the regulator which could result in a lean fuel condition.

Fuel Lock Off Valve
The fuel lock off valve is located before the DEPR and/or the vapor regulator. It is only open during cranking and running. This prevents the intake manifold from filling with gaseous fuel which could result in a backfire. The power is constant and supplied by the power relay. The ground of the solenoid is controlled by the GCP.

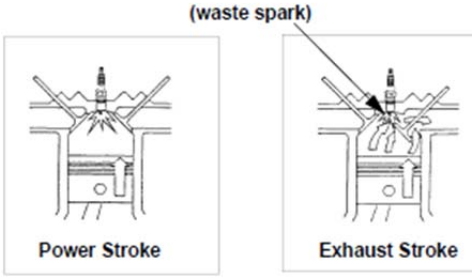
Distributor less Coil Pack

The ignition system controls fuel combustion by providing a spark to ignite the compressed air/fuel mixture at the correct time. To provide optimum engine performance, fuel economy, and control of exhaust emissions, the GCP controls the spark advance of the ignition system. Coil-on-plug ignition has the following advantages over a mechanical distributor system:

- No moving parts
- Less maintenance
- Remote mounting capability
- No mechanical load on the engine
- Elimination of mechanical timing adjustments
- Increased available ignition coil saturation time



The coil-on-plug design has individual coils mounted directly over each spark plug. Each cylinder is paired with its opposing cylinder in the firing order, so that one cylinder on compression fires simultaneously with the opposing cylinder on exhaust. The spark that occurs in the cylinder on the exhaust stroke is referred to as a “waste spark”.



The primary coils in the coil pack are triggered by the “ignition coil feed#1” and ignition coil feed #2” signals from the GCP.

Open Loop and Closed Loop Operation

NOTE: No DTC will be set unless engine has operated in closed loop status for more than 6 seconds.

The GCP will operate in the following two modes:

- Open loop
- Closed loop

When the engine is first started, the system is in "open loop" operation. In open loop, the GCP ignores the signal from the Heated Oxygen Sensor (HO2S). It uses a pre-programmed routine to calculate the air/fuel ratio based on inputs from the TP, ECT, TMAP & CKP sensors.

The system remains in open loop until the following conditions are met:

- The ECT has reached 75°F (24°C).
- 50 seconds has elapsed since starting the engine.

After these conditions are met, the engine is said to be operating in "closed loop". In closed loop, the GCP continuously adjusts the air/fuel ratio by responding to signals from the HO2S (except at wide-open throttle). When the HO2S reports a lean condition (low sensor signal voltage), the GCP responds by increasing the "on" time of the fuel injectors, thus enriching the mixture. When the HO2S reports a rich condition (high sensor signal voltage), the GCP responds by reducing the "on" time of the fuel injectors, thus leaning out the mixture.

Adaptive Learn
Adaptive Learn is a fuel correction coefficient that is derived from the closed loop correction and is stored in the GCP's memory.

The normal purpose of the Adaptive Learn is to compensate fuel flow for the following:

- Fuel composition variance
- Engine wear
- Component variation
- Component degradation

The GCP system will operate in closed loop plus adaptive learn when the ECT reaches 165°F.

NOTE: The adaptive learn coefficient will get erased if battery power falls below 9.5 volts.

GCP Service Precautions
The GCP is designed to withstand normal current draws associated with engine operation. When servicing the GCP, observe the following guidelines:

- Do not overload any circuit.
- When testing for opens and shorts, do not ground or apply voltage to any of the GCP's circuits unless instructed to do so.
- When measuring voltages, use only a digital voltmeter with an input impedance of at least 10 megohms.
- Do not employ any non-standard practices such as charging the battery with an arc welder.
- Take proper precautions to avoid static damage to the GCP. Refer to "electrostatic Discharge Damage" for more information.

Use of Circuit Testing Tools
Do not use a test light to diagnose the engine electrical systems unless specifically instructed by the diagnostic procedures. A test light can put an excessive load on a GCP circuit and result in component damage. For voltage measurements, use only a digital voltmeter with an input impedance of at least 10 megohms.

Electrostatic Discharge Damage
Electronic components used in the GCP are often designed to carry very low voltage. Electronic components are susceptible to damage caused by electrostatic discharge. Less than 100 volts of static electricity can cause damage to some electronic components. By comparison, it takes as much as 4000 volts for a person to feel the spark of a static discharge.

There are several ways for a person to become statically charged. The most common methods of charging are by friction and induction.

An example of charging by friction is a person sliding across a seat.

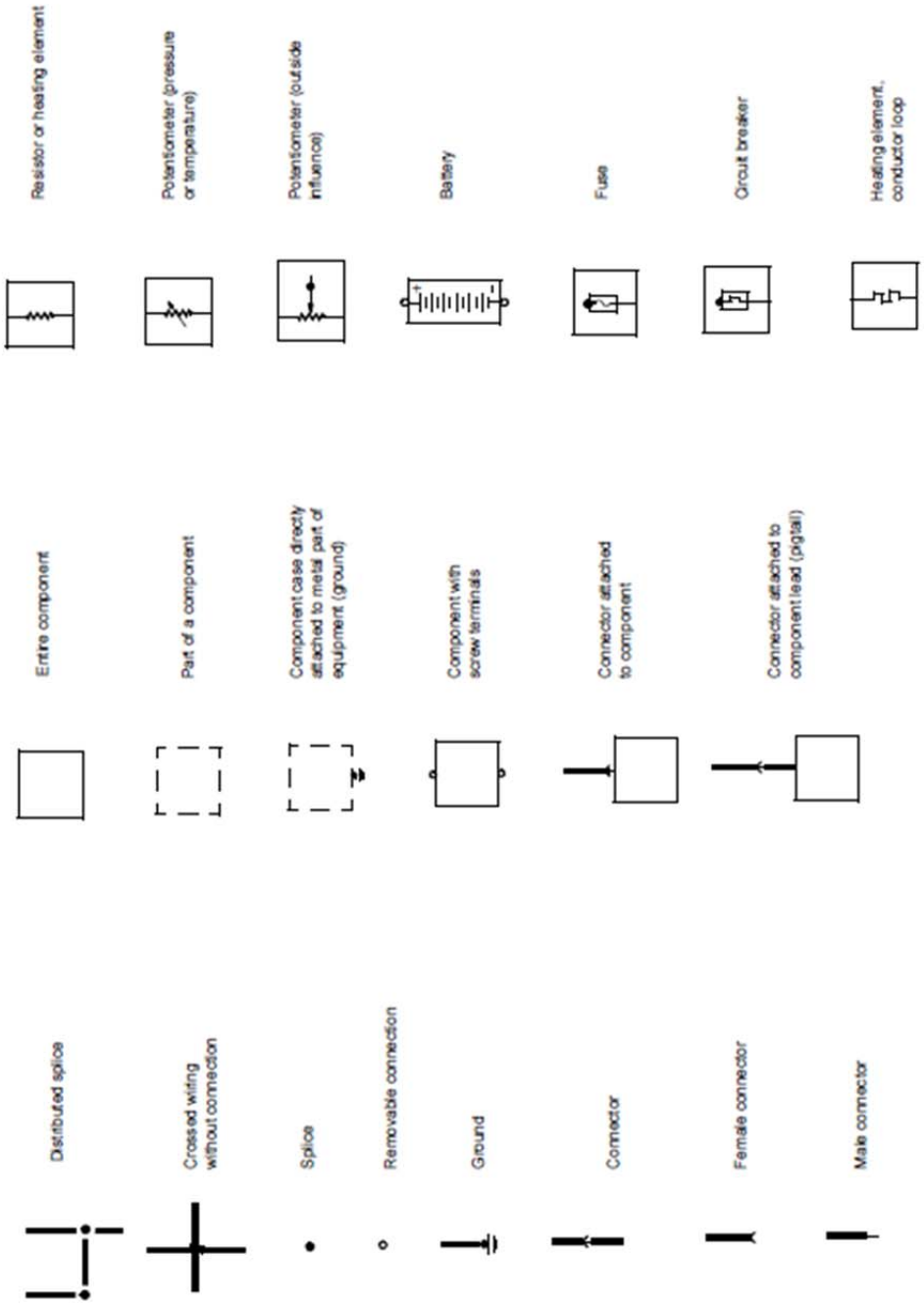
Charge by induction occurs when a person with well insulated shoes stands near a highly charged object and momentarily touches ground. Charges of the same polarity are drained off, leaving the person highly charged with the opposite polarity. Static charges can cause damage, therefore it is important to use care when handling and testing electronic components.

CAUTION: To prevent possible electrostatic discharge damage, follow these guidelines:

- Do not touch the GCP connector pins or soldered components on the GCP board.
- Do not open the replacement part package until the part is ready to be installed.
- Before removing the part from the package, ground the package to a known good ground on the equipment.
- If the part has been handled while sliding across a seat, while sitting down from a standing position, or while walking a distance, touch a known good ground before installing the part.

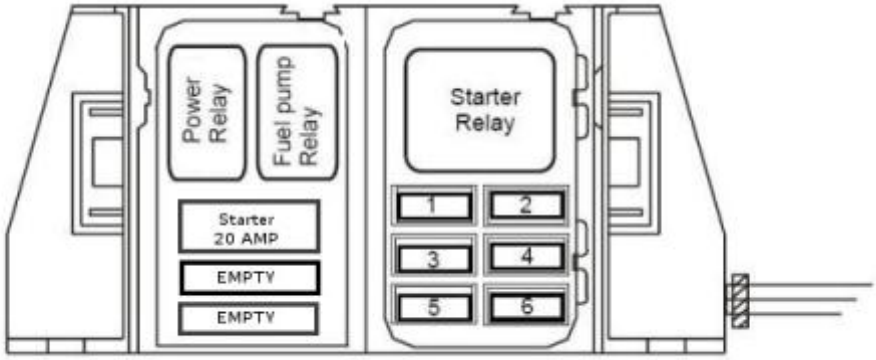
Diagrams and Schematics

Symbols



GCP - Power Distribution Box

Part of -5210070- Engine Wiring Harness



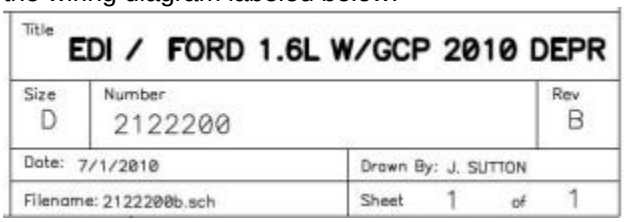
Fuse	Amps	Circuits protected
1	10	Battery Voltage to EPR
2	5	Ignition Voltage to GCP and Relays
3	10	Battery Voltage to GCP
4	15	Fuel pump
5	15	Battery Voltage out of Power Relay
6	10	Alternator

Wire Colors

Symbol	Color
BK	BLACK
BN	BROWN
BU	BLUE
DB	DARK BLUE
DG	DARK GREEN
GN	GREEN
GY	GRAY
LB	LIGHT BLUE
LG	LIGHT GREEN
NA	NATURAL
OG	ORANGE
PK	PINK
RD	RED
SR	SILVER
TN	TAN
VT	VIOLET
WH	WHITE
YE	YELLOW

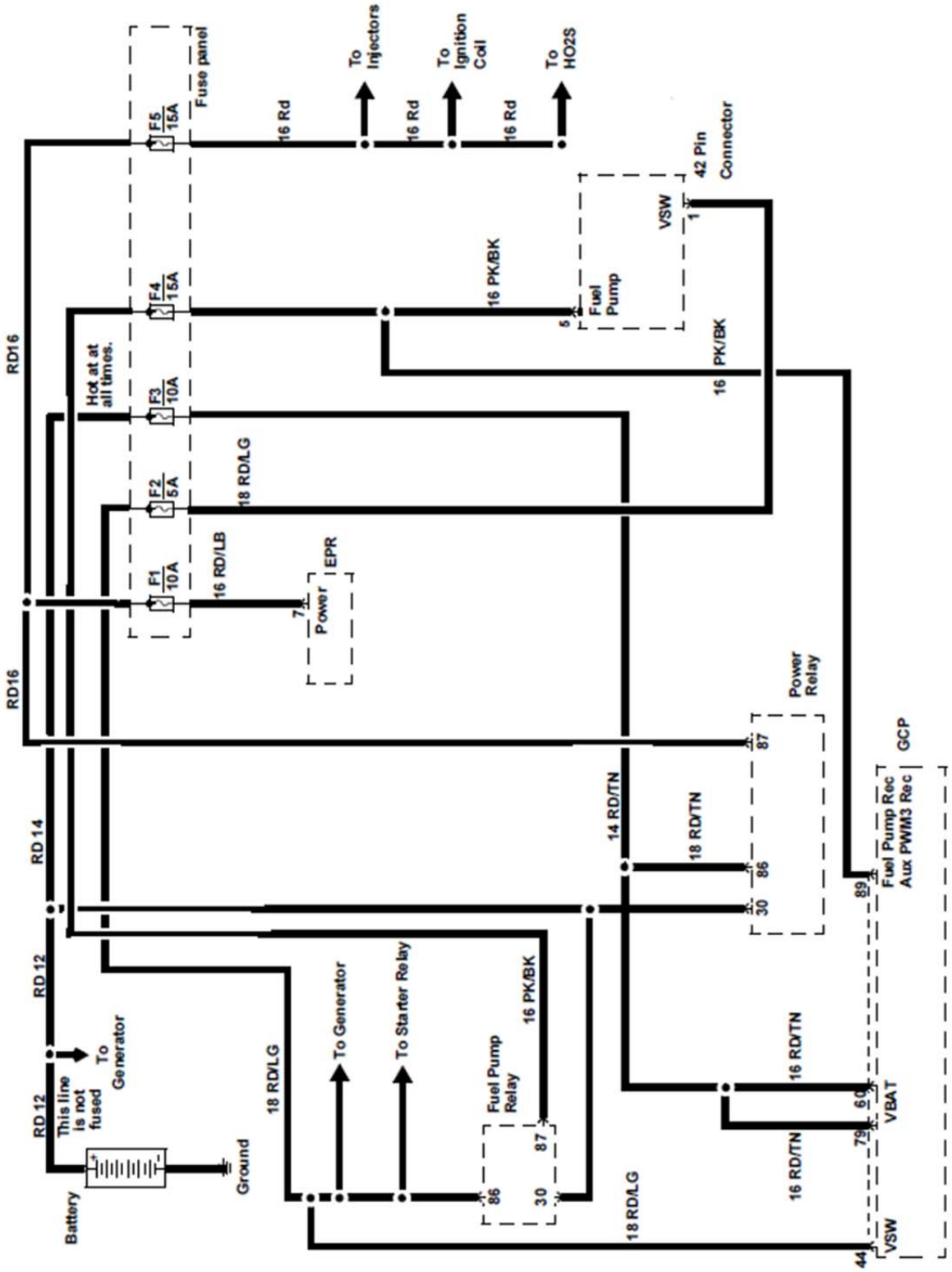
Revision Level

The following wiring schematics are taken from the wiring diagram labeled below:

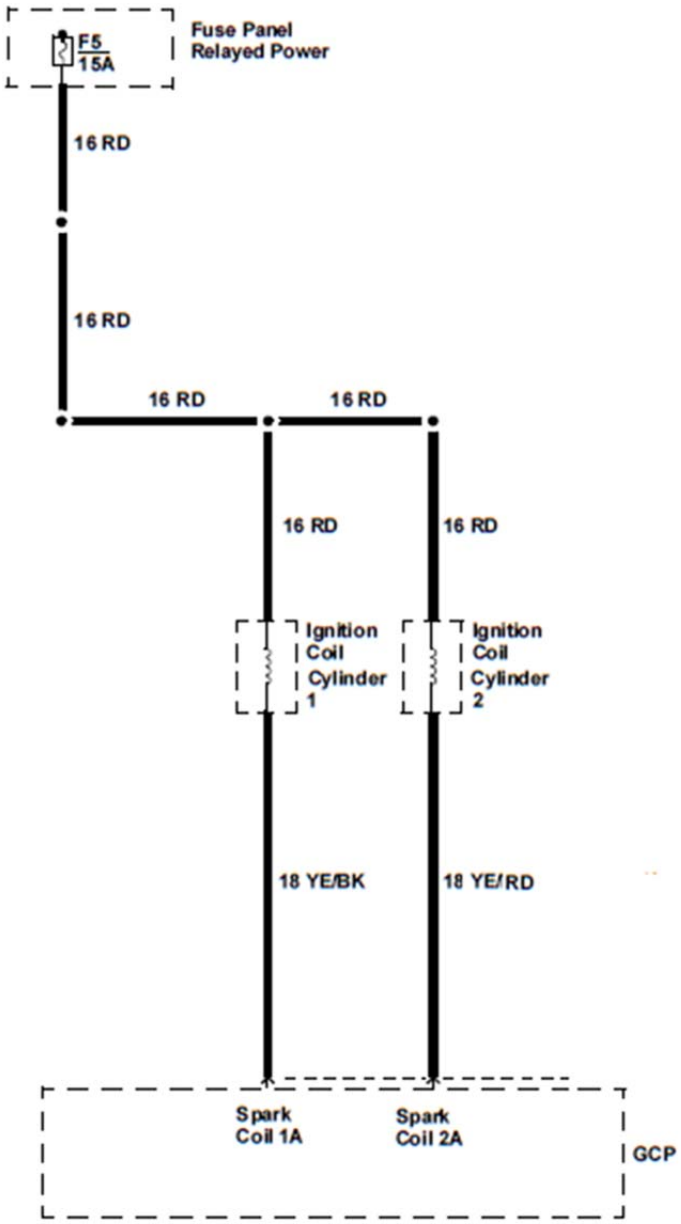


TSG-416 Engine Controls

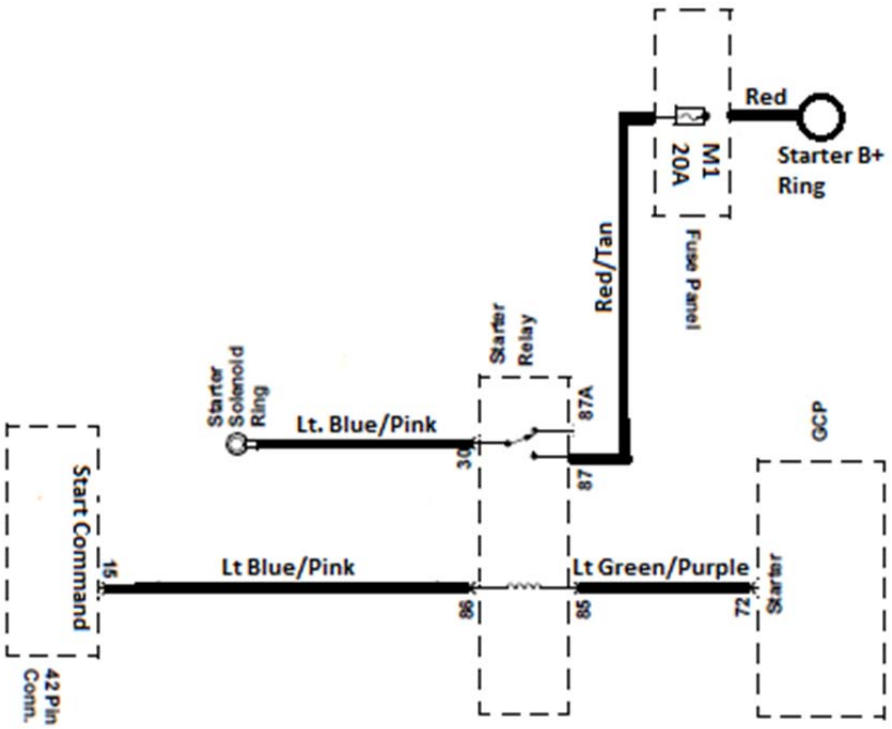
Power Distribution



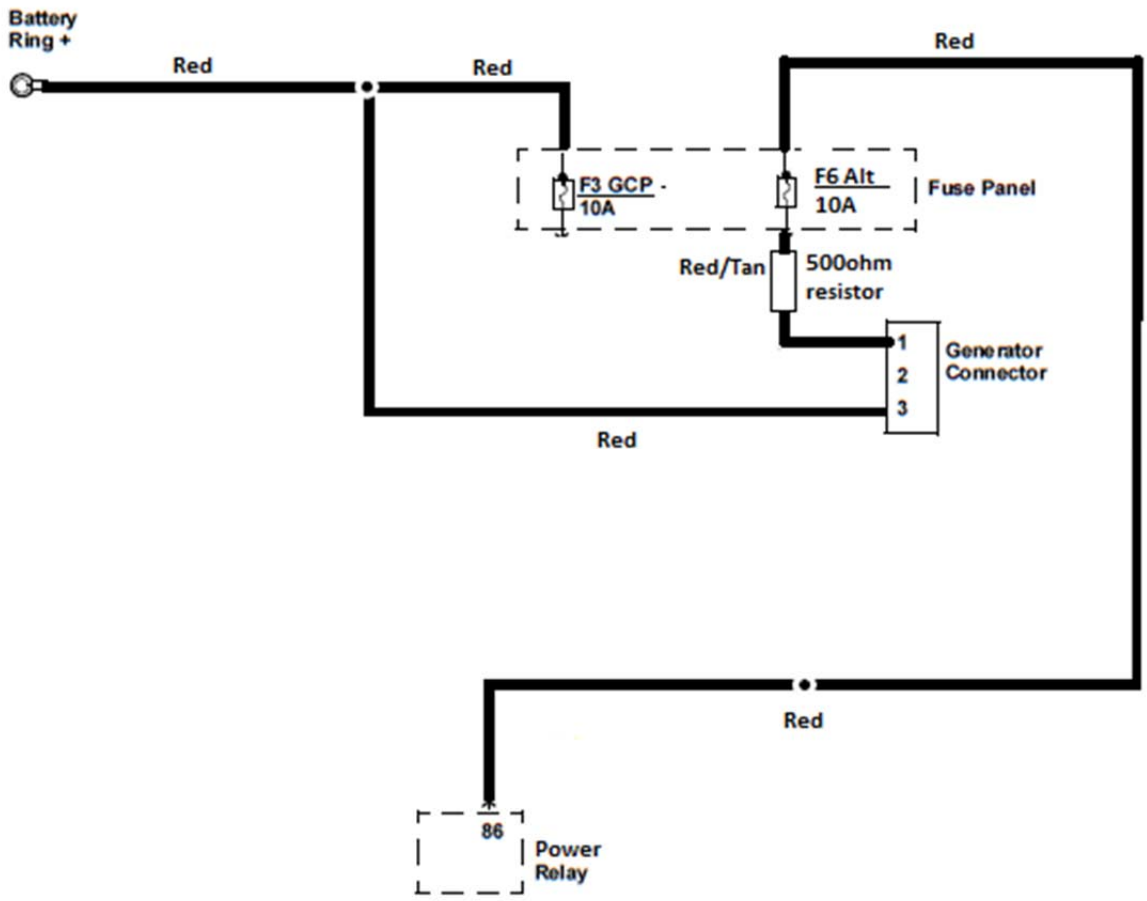
Ignition System



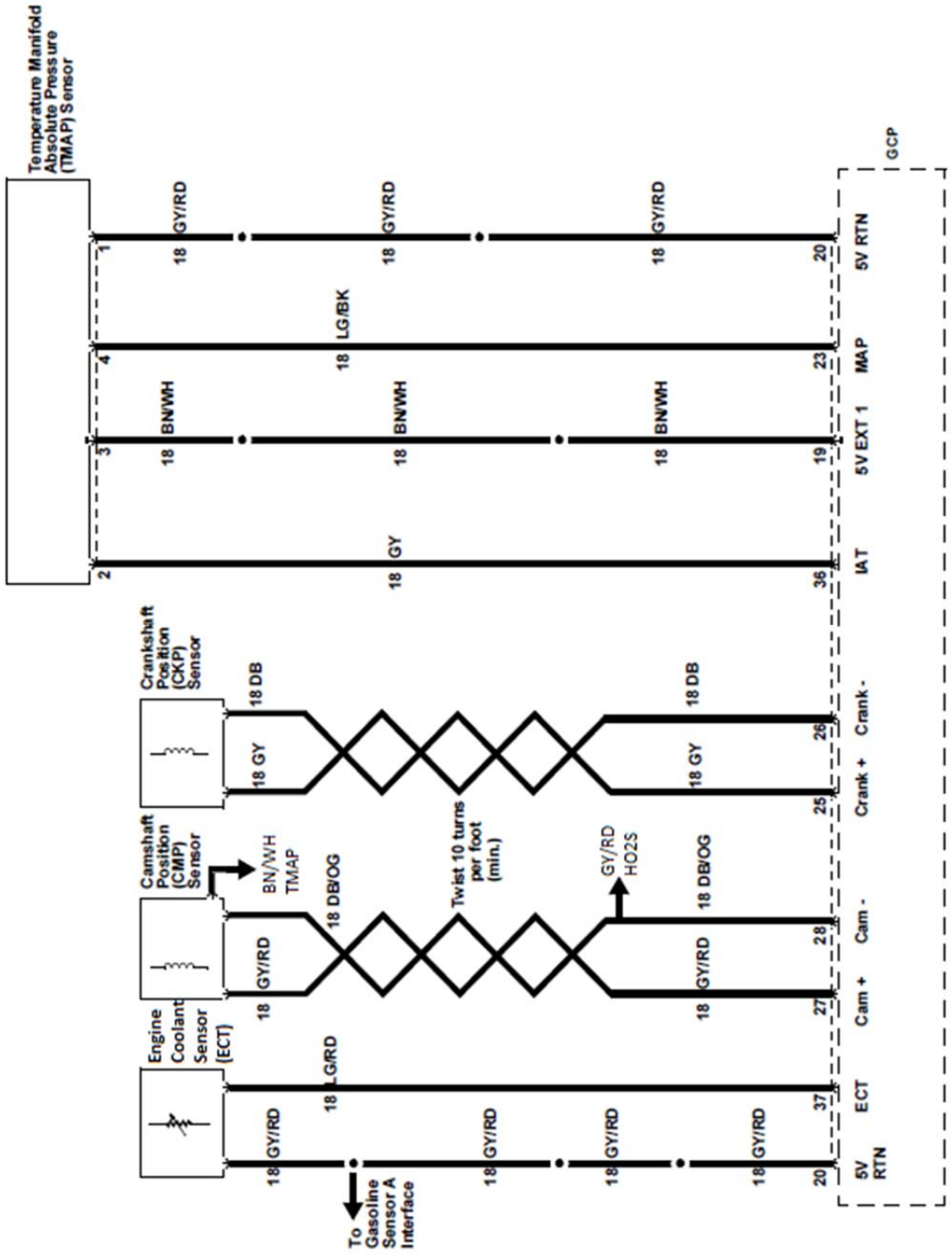
Starting System



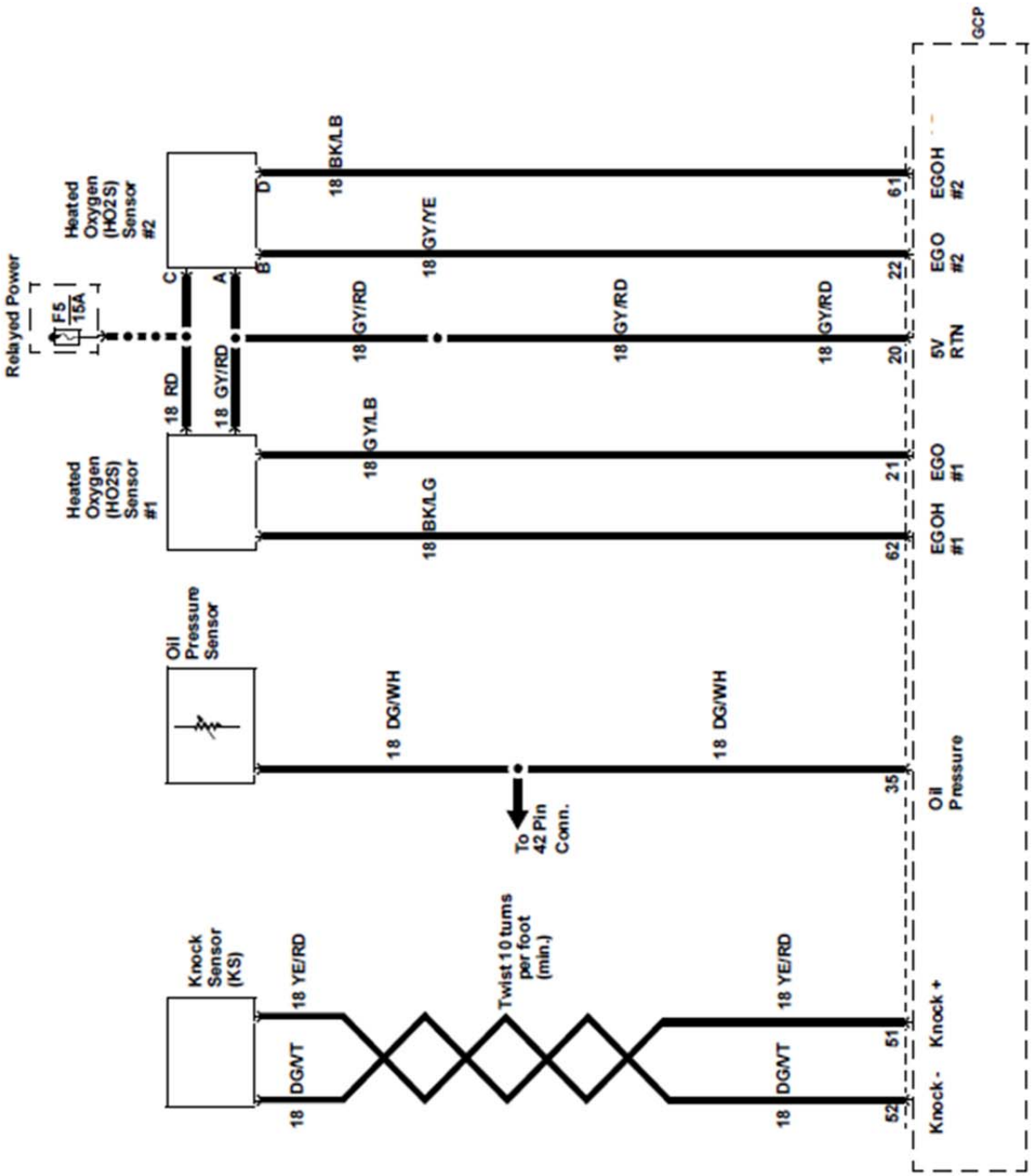
Charging System



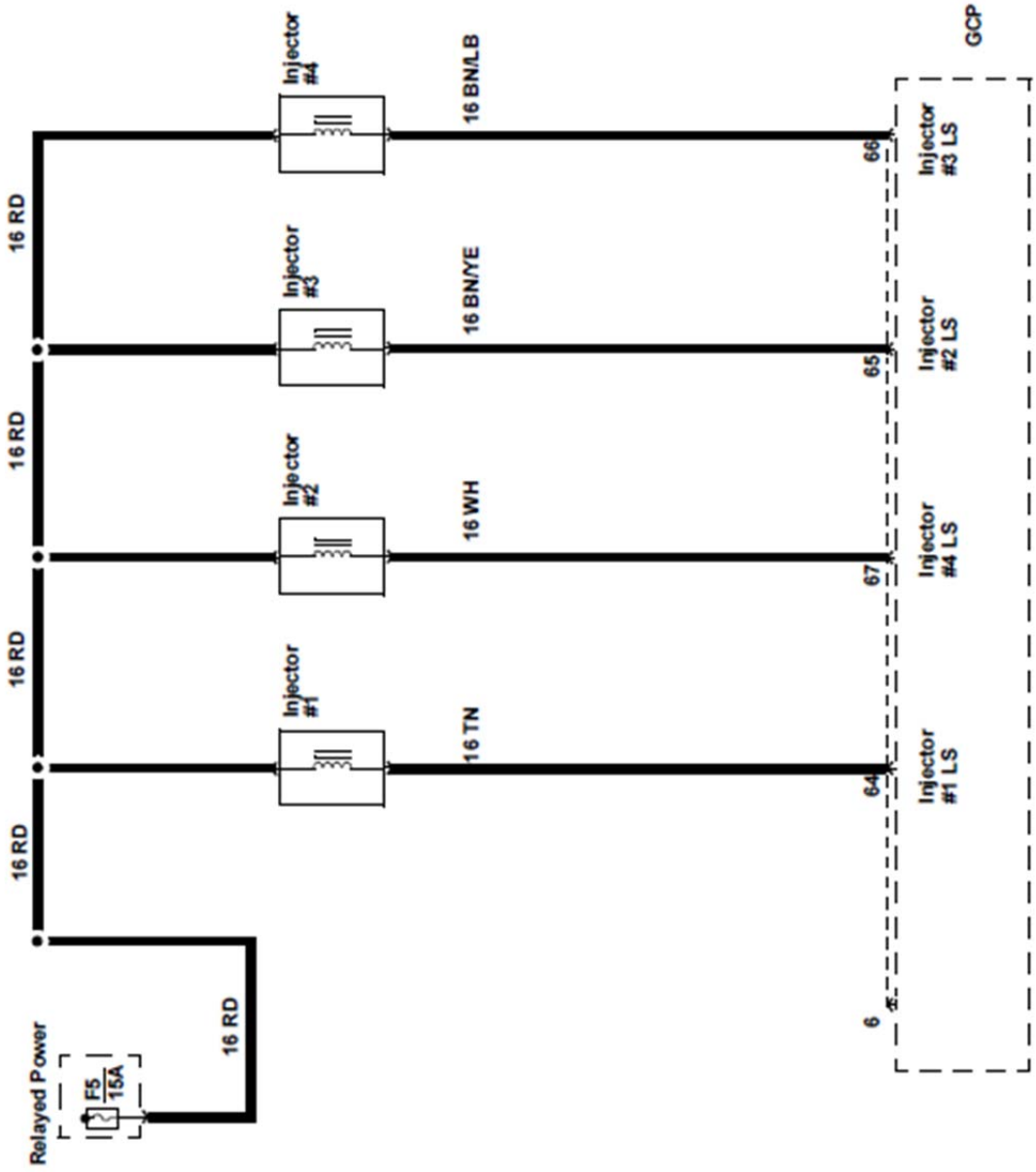
Engine Controls - Sensors (1 of 2)



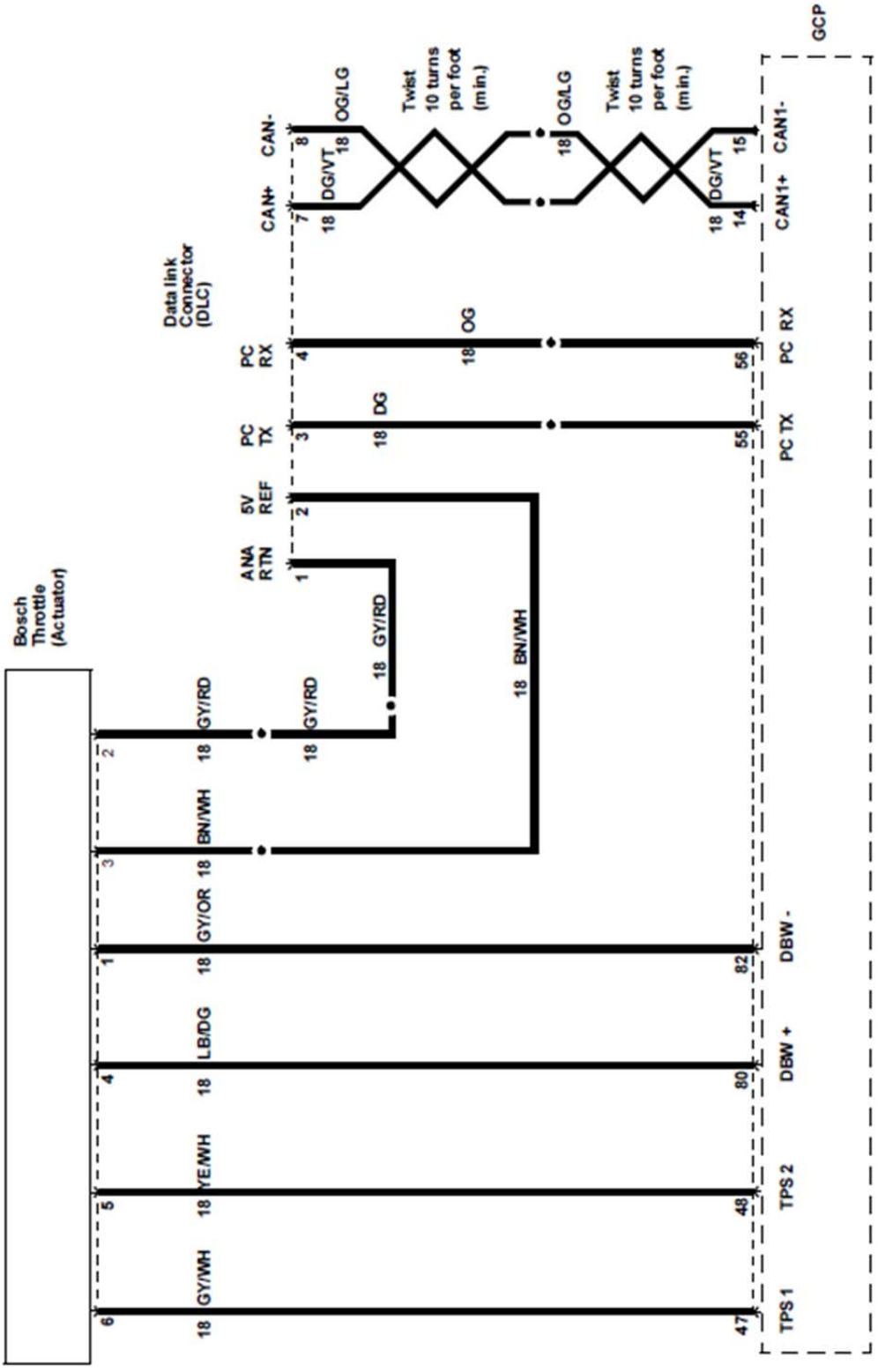
Engine Controls - Sensors (2 of 2)



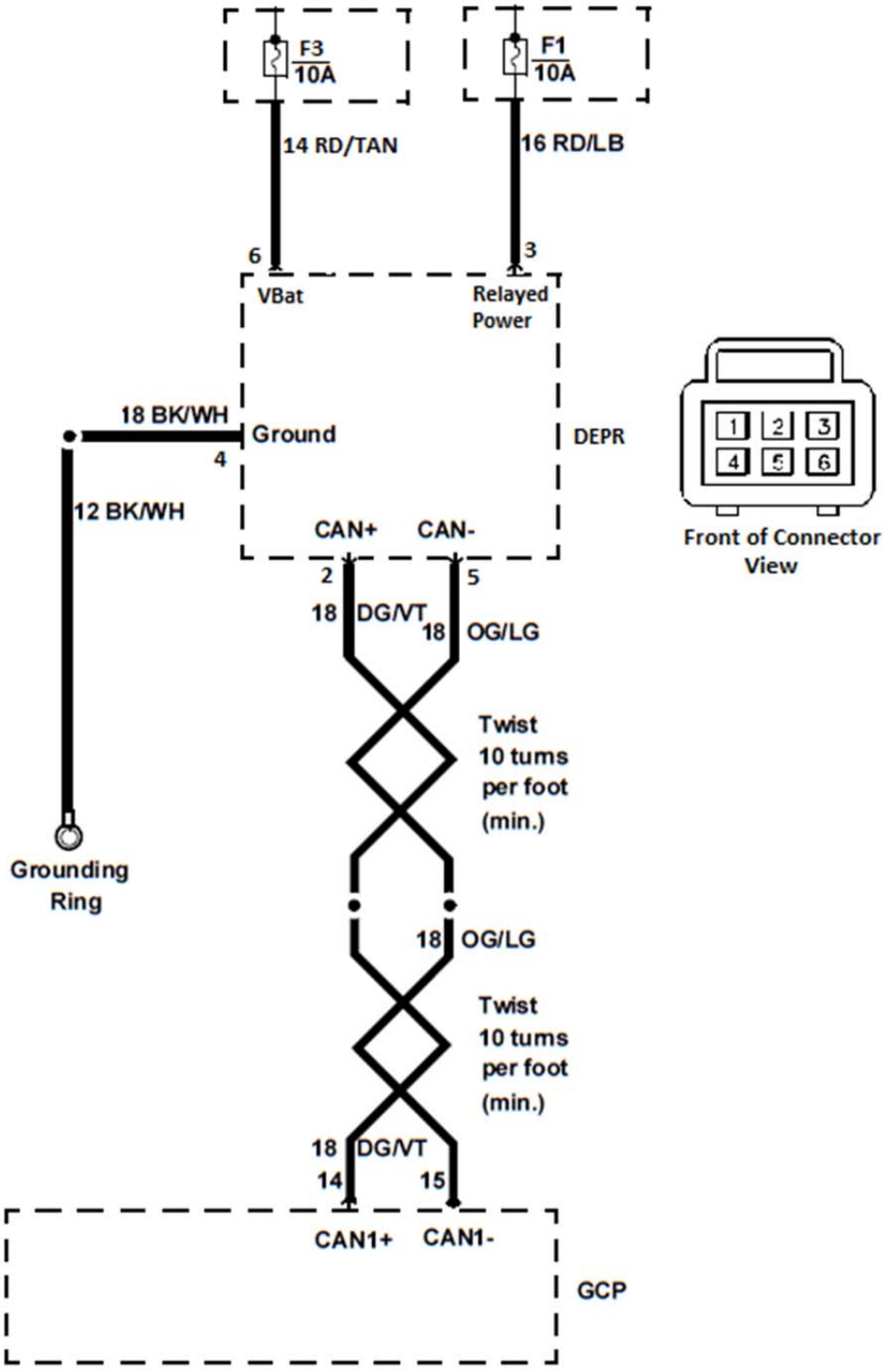
Fuel Injectors



Engine Controls - Actuator / Data Link Connector (DLC)



Engine Controls - Dry Fuel DEPR



DIAGNOSIS AND TESTING

Diagnostic Approach

Use the following step by step approach when diagnosing an engine performance problem:

1. Verify the concern and determine if it is a deviation from normal operation.
2. Once the concern has been verified, preliminary checks can be done. Conduct a thorough visual inspection, be alert for unusual sounds or odors, and gather diagnostic trouble code (DTC) information.
3. If a diagnostic trouble code (DTC) is stored, follow the designated DTC chart exactly to make an effective repair.
4. If no DTC is stored, select the symptom from the symptom charts and follow the suggestions to complete the repair.
5. If no matching symptom is available, analyze the complaint and develop a plan for diagnostics utilizing the wiring diagrams, technical assistance and repair history.
6. Some diagnostic charts contain diagnostic aids which give additional information about a system. Be sure to use all of the information that is available to you.

GCP Diagnostic Overview

FORD Diagnostic Trouble Codes are set when the FORD system GCP runs a diagnostic self-test and the test fails. When a DTC is set, the FORD system GCP will illuminate the Malfunction Indicator Lamp (MIL) on the instrument panel and save the code in memory.

The FORD system GCP will continue to run the self-test unless the DTC is an oxygen sensor lean, oxygen sensor rich, or a GCP related DTC. If the system continues to fail the test, the lamp will stay illuminated and the DTC is current (ACTIVE). All DTC's are stored as historical faults until they are cleared. All DTC's except the GCP related DTC's will automatically clear from memory if the DTC does not reset within 50 consecutive engine run cycles.

While a Diagnostic Trouble Code is current for a sensor, the FORD system GCP may assign a default limp home value and use that value in its control algorithms. All of the FORD system diagnostic self-tests run continuously during normal engine operation.

The Diagnostic Trouble Codes can be read by using either the Malfunction Indicator Lamp (MIL) or a Laptop computer. Refer to Using a Laptop Computer to Diagnose the FORD System and Using a Diagnostic Jumper to Diagnose the FORD System, located in this section. Diagnostic Trouble Codes can be cleared from memory with a laptop computer or by turning the ignition key to the OFF position and removing the FORD system main power fuse (F3) for 15 seconds.

If more than one DTC is detected, begin with the lowest number DTC and diagnose each problem to correction unless directed to do otherwise by the fault tree. The DTC's are numbered in order of importance. Having DTC 112 and DTC 122, both concerning the oxygen sensor, is possible. By repairing DTC 112 first, the problem causing the DTC 122 may also be corrected.

On-Board Diagnostics - GCP

The diagnostic tests and circuit charts are designed to assist the technician to locate a faulty circuit or component through a process of logical decisions. The tests and charts are prepared with the requirement that the engine functioned correctly at the time of assembly and that there were not multiple faults present.

There is a continuous self-diagnosis on certain control functions. This diagnostic capability is complimented by the diagnostic procedures contained in this section. The language for communicating the source of the malfunction is a system of diagnostic trouble codes.

When a malfunction is detected by the Engine Control Module (GCP), a Diagnostic Trouble Code (DTC) is set and the Malfunction Indicator (MIL) lamp will be illuminated (refer to MIL DTC Retrieval Procedure for process description) -- Refer to "Diagnosis Using a Personal Computer" on page 26 or Palm Pilot Diagnosis, for information regarding performing GCP and engine control system diagnosis.

Engine Control Module (GCP) Limp Home Mode Strategy

The GCP has four settings for limp home mode. Depending on what Diagnostic Trouble Code (DTC) is set, one or more of the limp home modes will be in effect.

The four limp home modes are as follows:

Power Derate 1

The actuator is limited to a maximum opening of 50%. If "Power Derate 1" is active, it will remain active until the active DTC goes away.

The following DTC's will cause Power Derate 1 to take affect:

- DTC 1521: CHT/ECT higher than expected 1. (CHT/ ECT is greater than 240 °F).
- DTC 111: IAT higher than expected 1. (IAT is greater than 200°F).
- DTC 327: Knock sensor open. (1.6L and 4.2L only)
- DTC 326: Excessive knock signal. (1.6L and 4.2L only)
- DTC 2122: FPP1 high voltage.
- DTC 2123 FPP1 low voltage.
- DTC 2128: FPP2 high voltage.
- DTC 2127: FPP2 low voltage.
- DTC 1531: IVS/Brake interlock failure.

Power Derate 2

The actuator is limited to a maximum opening of 20%. If "Power Derate 2" is active, it will remain active until the active DTC goes away and the ignition input to the GCP (usually the ignition switch) is cycled.

- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.
- DTC 1171: MegaJector delivery pressure higher than expected.
- DTC 1172: MegaJector delivery pressure lower than expected.
- DTC 1173: MegaJector communication lost.
- DTC 1176: MegaJector internal actuator fault detection.
- DTC 1177: MegaJector internal circuitry fault detection.
- DTC 1178 MegaJector internal communication fault detection.
- DTC 606: COP failure (Internal GCP failure).
- DTC 1612: RTI 1 loss (internal GCP failure).
- DTC 1613: RTI 2 loss (internal GCP failure).
- DTC 1614: RTI 3 loss (internal GCP failure).
- DTC 1615: A/D loss (internal GCP failure).
- DTC 1616: Invalid interrupt (internal GCP failure).
- DTC 601: Flash checksum invalid (internal GCP failure).
- DTC 604: RAM failure (internal GCP failure).

Fault Low Rev Limit
The engine RPM will be limited to a maximum of 1600 RPM. If the "Fault Low Rev Limit" is active, it will remain active until the active DTC goes away and the ignition input to the GCP (usually the ignition switch) is cycled.

- DTC 2122: FPP1 high voltage.
- DTC 2123: FPP1 low voltage.
- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.
- DTC 1531: IVS/Brake interlock failure.

Force to Idle
The engine RPM will be limited to a maximum of 800 RPM. If the "Force to Idle" is active, it will remain active until the active DTC goes away.

- DTC 2122: FPP1 high voltage.
- DTC 2123: FPP1 low voltage.
- DTC 2128: FPP2 high voltage.
- DTC 2127: FPP2 low voltage.
- DTC 2115: FPP1 higher than IVS limit.
- DTC 2139: FPP1 lower than IVS limit.
- DTC 2116: FPP2 higher than IVS limit.
- DTC 2140: FPP2 lower than IVS limit.
- DTC 2126: FPP1 higher than FPP2.
- DTC 2121: FPP1 lower than FPP2.

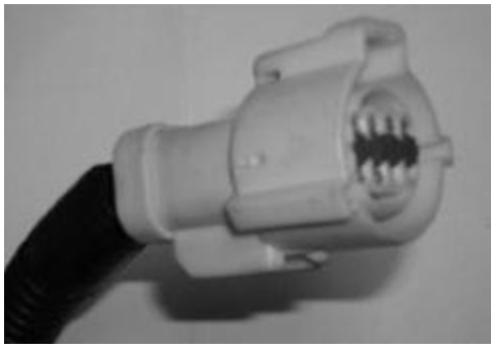
Intermittent MIL

Conditions that are only present from time to time are called intermittents. To resolve intermittents, perform the following steps:

1. Evaluate the history of DTC's observed with this particular engine.
2. Evaluate the symptoms and conditions described by the customer.
3. Use strategy-based diagnosis, especially where it relates to the elimination of bad connectors and wiring.
4. When using a personal computer with Ford software, data-capturing capabilities are available that can assist in detecting intermittents. Review the user manual pdf document that is included on the software CD.

Malfunction Indicator Lamp (MIL) DTC Retrieval Procedure

NOTE: DTC's can be retrieved from the engine control module (GCP) by using either the MIL or an IBM compatible personal computer with a USB port. Refer to Equipment Setup for information about using a personal computer to assist with unit diagnosis.



DTC's can be retrieved by shorting the Self-Test Input (STI) connector to ground. The STI circuit is a white/ purple wire exiting pin 3 of the 42 pin connector. The STI white/purple wire branches off to terminal "A" of the 4 pin diagnostic connector. If no DTC is stored with key on/engine off (KOEO), a DTC 123 is flashed, indicating that all systems are OK.

During key on/engine running (KOER) operation, with no DTCs stored, the MIL is not illuminated. If during

KOER operation a DTC is stored, the MIL will illuminate and remain on steady if the code is active.

MIL Bulb Test

The MIL bulb test occurs KOEO with the STI connector not grounded. The MIL bulb will stay on and remain on if no DTCs are present. If DTCs are present (except DTC 123), the MIL bulb will blink. If the MIL bulb does not illuminate when bulb test is performed, access diagnostic software and view the fault indicator on screen. If the screen fault indicator is illuminated and the MIL light is not, inspect the bulb and replace it if damaged. If bulb is OK or does not illuminate after replacement, refer to MIL circuit test procedure. Once MIL bulb illumination has been verified or established, DTCs can be extracted from the MIL as follows:

DTC Extraction

- KOEO, short the STI circuit to a known good ground. There will be a 5 second delay before DTCs begin flashing.

When extracting DTCs via the MIL the following apply:

- The flashing MIL is on for 0.4 second and off for 0.4 second.
- The MIL is off for 1.2 seconds between digits of three digit DTCs.
- The MIL is off for 2.4 seconds between DTCs.
- Each DTC repeats 3 times before the next stored DTC begins flashing
- Up to 6 DTCs can be stored.
- Once all stored DTCs are flashed, the process repeats with the first stored DTC.
- DTCs are flashed in the order in which they were set.

Once the DTC(s) is retrieved, refer to the appropriate DTC chart for explanation of what caused the DTC to set. Perform component and circuit test as required to conduct repair.

Diagnosis Using a Personal Computer

Equipment Requirements

You will need a laptop computer with a USB Port and CD drive.

- Kit for laptop part #: 5080050
  - ECOM Cable
  - Software CD

The required software is included with the kit via a CD.

Laptop Requirements:

• USB port
• 800 x 600 dpi screen
• Windows 95 or newer operating system
• No speed minimum
• 32 MB of RAM

Interface Hook-Up
For a connection to a laptop, use the below ECOM cable (5080050).

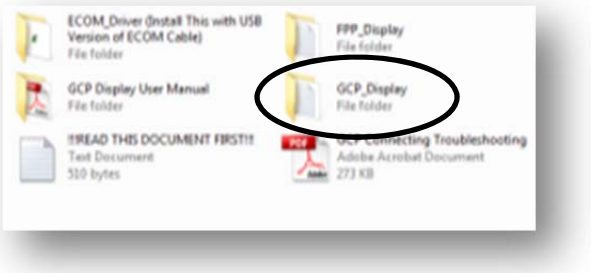
GCP Software Installation

Insert CD into CD-ROM drive.

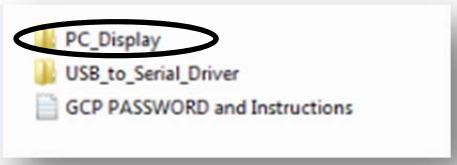
Double click “My Computer” Icon.

Double Click CD-ROM drive letter

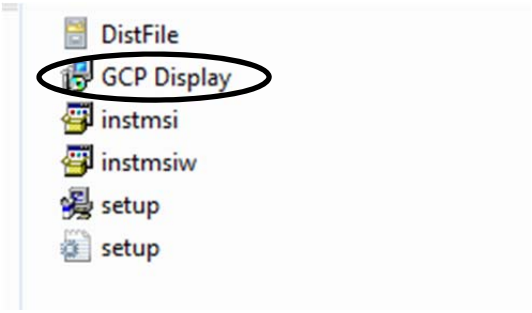
This will display the contents of the CD as shown.



Double click GCP_Display folder.



Double click the PC_Display folder.

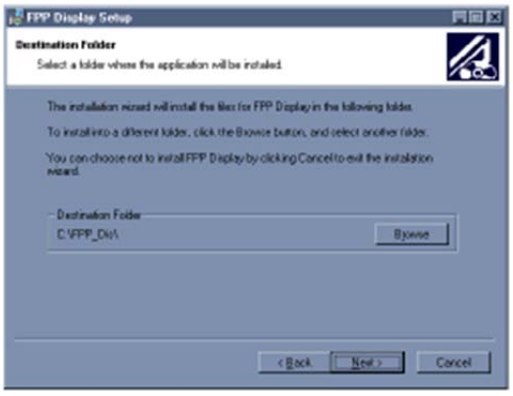


Double click the GCP_Display icon.

You will now see a welcome screen.

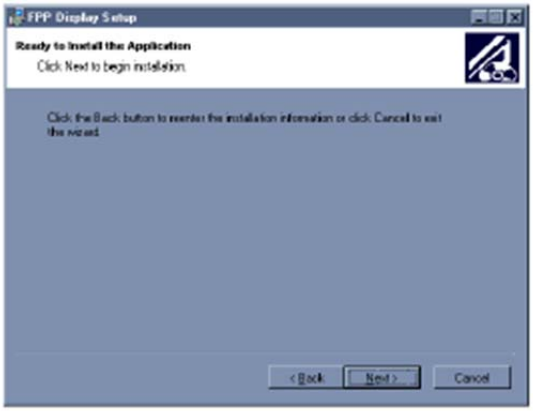
Click next.

A screen will pop up telling you the name of the destination folder.



Click next.

You will now see a screen telling you it is ready to install the software.



Click next.

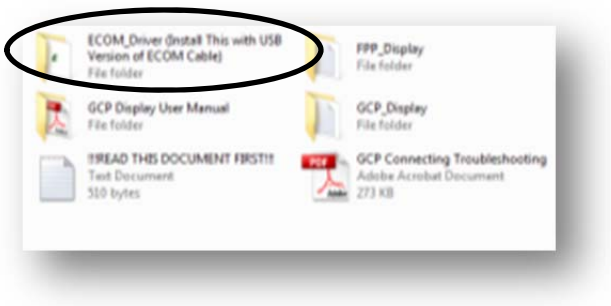
You will see an Installation Success" screen when the software is finished installing.

Click Finish.

A screen will pop up asking if it is ok to reboot your system.

Click No.

Go back to the main CD folder.



Double click the ECOM driver folder.

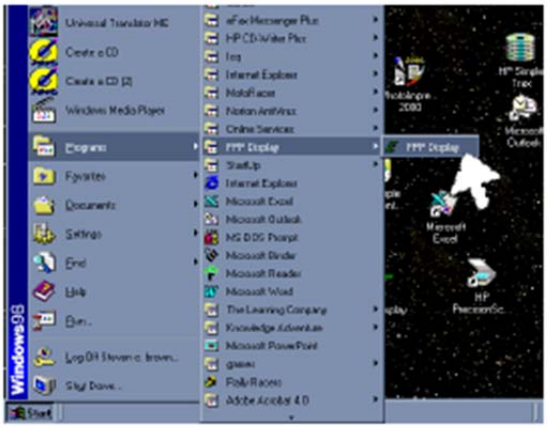
Double click the Driver Setup icon.

Follow those install instructions. Once successfully installed reboot your system.

The software is now installed on your system in a folder called "GCP Display". Refer now to "Using Technicians GCP Software" in this Section.

Using GCP Software - Menu Functions

You can begin using the technicians GCP software after installation, by clicking Start - Programs - GCP Display - GCP Display as shown.



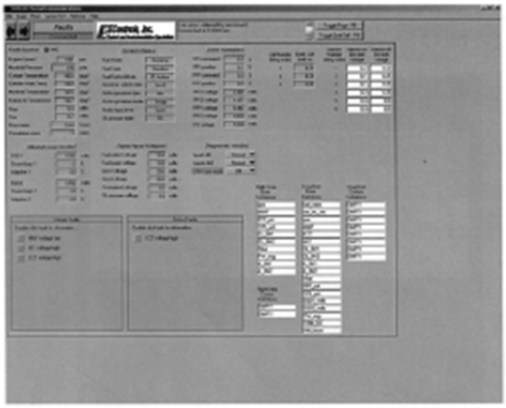
Type in the Password which can be found in the text file on the CD in the GCP Display folder.

Place the ignition key in the ON position.

The GCP system Gauge screen should now appear and a green banner in the upper left hand corner will read "Connected".

Diagnostic Trouble Codes

The System Fault screen is used to view and clear DTC's, which have been set.



Checking Diagnostic Trouble Codes

The System Fault screen contains a listing of all of the Historic and Active DTC's set within the GCP system. If a DTC is stored in memory, the screen will display that fault in the Historic Faults column. If the fault condition currently exists, the DTC will also show up in the Active Faults column.

Opening Diagnostic Trouble Codes

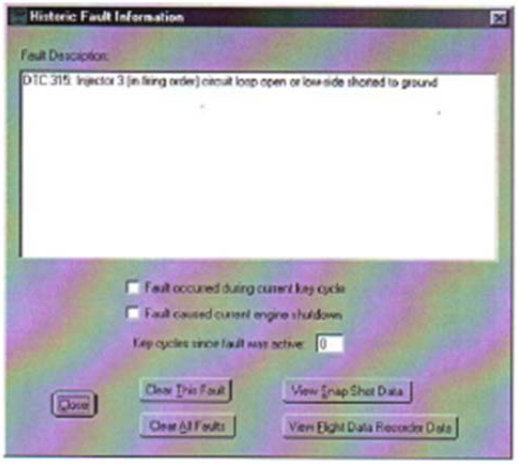
To open a DTC, click on the DTC in the Historic Faults column. A DTC Dialog Box will pop up on the screen. The DTC Dialog Box contains the following useful information:

- If the fault occurred during the current key cycle.
- If the fault caused current engine shutdown.
- How many key cycles since the fault was active.
- Snapshot Data (explained later).
- Flight Data Recorder (explained later).

The DTC Dialogue Box also allows you to clear a single fault by clicking on the "Clear This Fault" button and it allows you to clear all faults by clicking on the "Click All Faults" button.

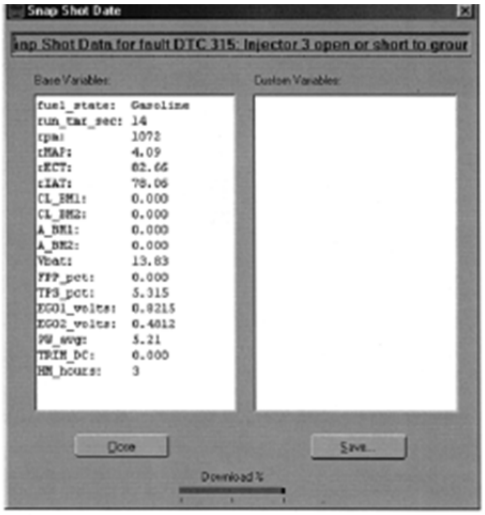
NOTE: Record faults before clearing them. This will aid in diagnosis.

Below is an example of a DTC Dialogue Box.



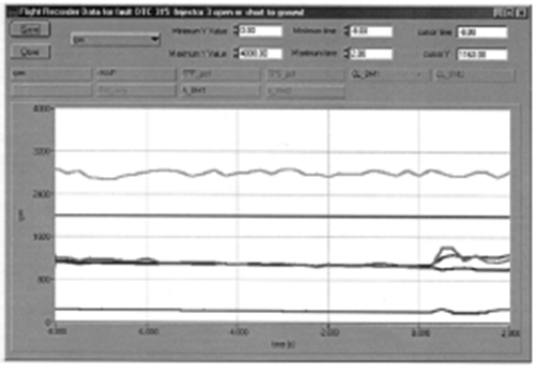
Snap Shot Data

The Snap Shot Data is a listing of specific engine system variables. These variables are recorded by the GCP at the instant the DTC sets. By clicking on the "View Snap Shot Data" button, a new window will pop up and you will be able to view these variables. Here is an example of a Snap Shot Data window.



Flight Data Recorder
The Flight Data Recorder is also a listing of specific engine system variables. These variables are recorded by the GCP for an interval of 10 seconds. The 10 second interval includes 8 seconds before the DTC sets and 2 seconds after the DTC sets. By clicking on the "View Flight Data Recorder Data" button, a new window will pop up and you will be able to view these variables.

Below is an example of a flight Data Recorder Data window.



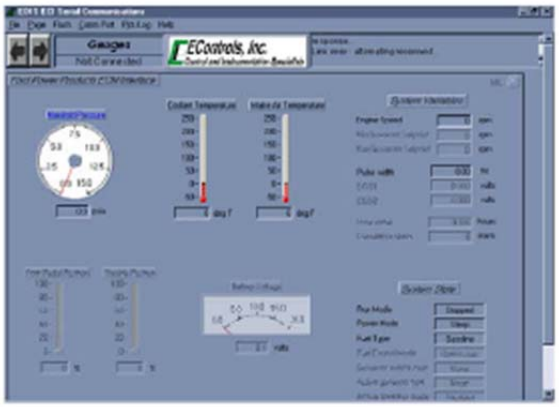
The FAULTS screen shows the following:

- Fault Access
- System States
- DBW Variables
- Closed Loop Control
- Digital Input Voltages
- Diagnostic Modes
- Historic Faults
- Active Faults

Use the keys at the upper left corner or the "page" command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

Data Stream - Reading Sensor & Actuator Values



Most applicable sensor and actuator values are displayed on the Gauges Screen. The display shows the voltage the FORD system GCP is reading and, for sensors, the sensor value in engineering units.

This is one of three main screens (GAUGES, FAULTS AND RAW VOLTS).

The GAUGES screen shows the following:

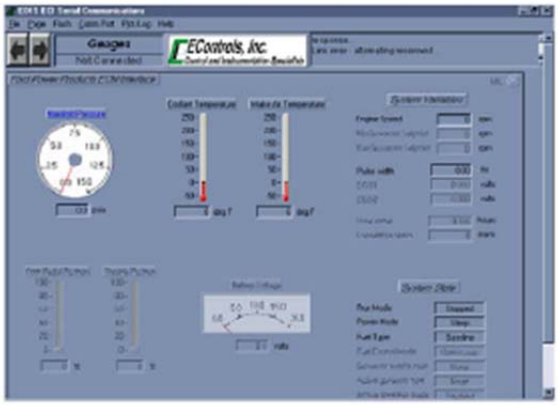
- Manifold Absolute Pressure (MAP)
- Engine Coolant Temperature (ECT)
- Intake Air Temperature (IAT)
- Throttle Position (TP)
- Foot Pedal Position (FPP)
- Battery Voltage
- Engine speed (RPM)
- Exhaust Gas Oxygen (HO2S)
- Hour meter
- Number of continuous starts
- Run mode, power mode and fuel type

Use the keys at the upper left corner or the "page" command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

NOTE: If a DTC for a sensor is current, the engineering value for that sensor may be a default, limp home value and the voltage value will be the actual sensor voltage. Use the voltage value when performing diagnostics unless directed to do otherwise by the diagnostic trouble tree.

Plotting and Data Logging



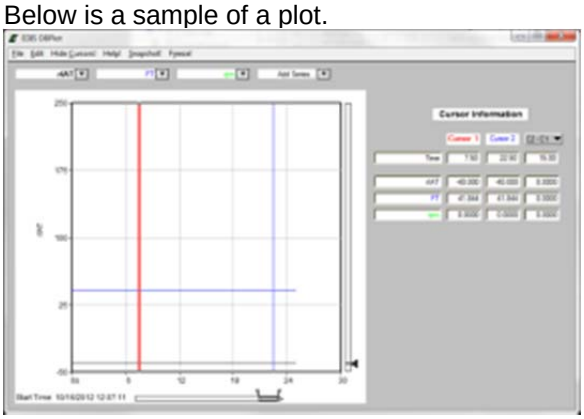
Recording the values and voltages can be a very useful tool while diagnosing engine problems. The GCP diagnostic software includes real time **plotting** and real time **logging** capabilities. These features enhance the ability to diagnose and repair possible problems with the GCP system. Both plotting and logging allows the user to record, in real time, any variable that can be seen in the GCP_Dis software. In order to record variables, the GCP_Dis software must be "Connected" to the GCP.

Plotting

To plot a variable, you must first "TAG" the variable. To do this, use the mouse to right click on the variable. The variable will highlight in green to let you know it is "TAGGED". Next, press the "P" key or click the Plot/Log button and then click the Plot Tags button to invoke the plotting feature. This begins the plot function and you can observe the plotted variables. The plot sweeps from right to left. To stop the plotting feature, simply click the "Freeze". To restart the plotter, click on the "Resume" button. The maximum number of variables that can be plotted at one time is 10. The range of the selected variables will be shown on the Y-axis and the time will be shown on the x-axis. You may change the desired time interval and sample interval for the plot by stopping the plot and typing in a new intervals.

The plot can be saved to the PC by stopping the plot and clicking "File" then "SAVE". When saving a plot, you will have to type in a filename. Plot files can later be viewed with the edis_saplot software located in the Windows Start Programs GCP_Dis folder, or the data can be viewed in Notepad or Excel.

Below is a sample of a plot.



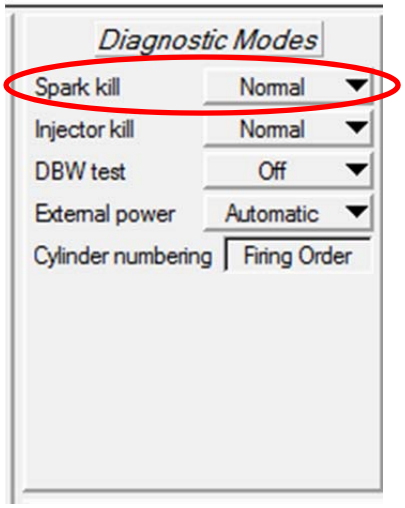
Logging

Logging variables means the variables are stored to the PC. During logging, there is no plot shown on the screen. To log variables you must first "TAG" the variables by right clicking them (same as plotting). Next, click on Plot / Log and then Log Tags. An "Edis Log" window will pop up. You can type in a custom log File name or select a custom folder to save the log file to. The default filename is "edis.log" and the default folder is GCP_Dis. The sample interval and time interval can also be changed from the default. To start logging, click on the "START" button. You will see the progress bar moving from 0 to 100%. When the logging is complete, you can close the Edis Log box or start another log file. If you start another log file, you must change the Log File name or the first log file will be overwritten. To view the contents of a saved log file, you can use Notepad or Excel.

The following are examples showing the Edis Log box before starting a log file, when running the log file the progress bar will move.

TSG-416 Engine Controls

Ignition System Test



The Spark Kill diagnostic mode allows the technician to disable the ignition on individual cylinders. If the Spark Kill diagnostic mode is selected with the engine running below 1000 RPM, the minimum throttle command will lock into the position it was in when the test mode was entered. If the Spark System Test mode is selected with the engine running above 1000 RPM, the throttle will continue to operate normally.

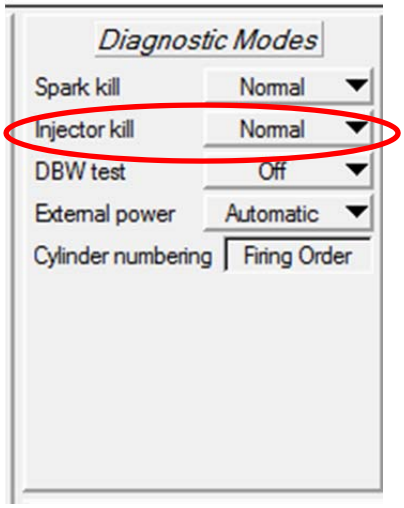
Spark kill is only available on gasoline, NOT on gaseous fuels.These diagnostic modes are found on the faults page.

Disabling Ignition Ouputs

To disable the ignition system for an individual cylinder, use the mouse to highlight the “Spark Kill” button and select the desired coil. The spark output can be re-enabled by using the mouse to highlight the “Spark Kill” button and selecting “Normal”. If the engine is running below 1000 RPM, the spark output will stay disabled for 15 seconds and then re-set. If the engine is running above 1000 RPM, the spark output will stay disabled for 5 seconds and then reset.
This test mode has a timeout of 10 seconds. Record the rpm drop related to each spark output disabled.

The Spark outputs are arranged in the order which the engine fires, not by cylinder number.

Injector Test

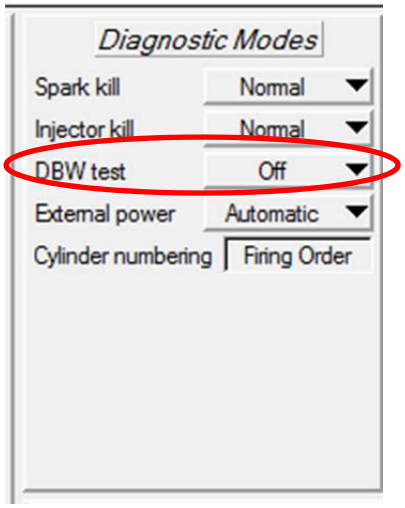


The Injector Kill mode is used to disable individual fuel injectors. If the Injector Kill mode is selected with the engine running below 1000 RPM, the minimum throttle **command** will lock into the position it was in when the test mode was entered. If the Injector Kill mode is selected with the engine running above 1000 RPM, the throttle will continue to operate normally.

Disabling Injectors

To disable an injector, use the mouse to select the desired injector. The word “Normal” will change to the Injector you have selected. The injector driver can be re-enabled by selecting again. If the engine is running below 1000 RPM, the injector driver will stay disabled for 15 seconds and then re-set. If the engine is running above 1000 RPM, the injector driver will stay disabled for 5 seconds and then re-set. Record the change in rpm or closed loop multiplier while each driver is disabled.

Throttle Test



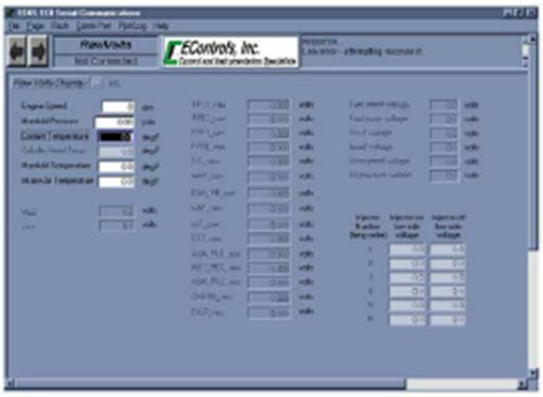
To select this test mode the engine must be off, but the key must be in the ON position.

The DBW Test mode allows the technician to control the throttle directly (without the engine running) with the foot pedal or entering a number into the “TPS Command” box. It is used during the diagnostic routines specified for FPP (foot pedal position) and TPS (throttle position sensor) related faults.

FP position displays the current position of the foot pedal as a percentage. FPP volts display the voltage that the GCP is reading from the FPP sensor.

TPS Command displays the commanded throttle position expressed as a percentage, which is being sent to the throttle. TPS Position is the actual percent of throttle opening being sent to the GCP from the throttle. TPS volts display the actual TPS signal voltage the GCP is receiving from the throttle.

RAW VOLTS Screen



The RAW VOLTS screen shows actual voltage readings from various circuits.

Use the keys at the upper left corner or the “page” command to toggle the three main screens (GAUGES, FAULTS AND RAW VOLTS).

NOTE: F9 key will toggle to the last screen you were on.

Visual Inspection

Perform a careful visual and physical engine inspection before performing any diagnostic procedure. Perform all necessary repairs before proceeding with additional diagnosis, this can often lead to repairing a problem without performing unnecessary steps. Use the following guidelines when performing a visual/physical inspection check:

- Inspect engine for modifications or aftermarket equipment that can contribute to the symptom; verify that all electrical and mechanical loads or accessory equipment is “OFF” or disconnected before performing diagnosis.
- Inspect engine fluids for correct levels and evidence of leaks.
- Inspect vacuum hoses for damage, leaks, cracks, kinks and improper routing, inspect intake manifold sealing surface for a possible vacuum leak.
- Inspect PCV valve for proper installation and operation.
- Inspect all wires and harnesses for proper connections and routing; bent or broken connector pins; burned, chafed, or pinched wires; and corrosion. Verify that harness grounds are clean and tight.
- Inspect GCP, sensors and actuators for physical damage.
- Inspect GCP grounds for cleanliness, tightness, and proper location.
- Inspect fuel system for adequate fuel level, and fuel quality (concerns such as proper octane, contamination, winter/summer blend).
- Inspect intake air system and air filter for restrictions.
- Inspect battery condition and starter current draw.

If no evidence of a problem is found after visual inspection has been performed, proceed to “Diagnostic System Check”

Intermittent Problems

NOTE: An intermittent problem may or may not turn on the MIL or store a DTC. Do not use the DTC charts for intermittent problems. The fault must be present to locate the problem.

NOTE: Most intermittent problems are caused by faulty electrical connections or wiring. Perform a careful visual inspection for the following conditions:

- Poor mating of the connector halves or a terminal not fully seated in the connector (backed out).
- Improperly formed or damaged terminals
- Improper contact tension. All connector terminals in the problem circuit should be carefully checked.
- Poor terminal-to-wire connections. This requires removing the terminal from the connector body to check.
- Improperly installed aftermarket equipment or accessories.

Operate the engine with accessories “OFF” and a suitable multimeter connected to the suspected circuit. An abnormal voltage when the malfunction occurs is a good indication that there is a fault in the circuit being monitored.

To check GCP for loss of diagnostic code memory, disconnect the MAP sensor connector and idle the engine until the MIL illuminates. Perform MIL DTC retrieval procedure. DTC should be stored and kept in memory when the ignition is turned “OFF”. If not, the GCP is faulty. When this test is completed, make sure that you clear the DTC from memory. An intermittent MIL with no stored DTC may be caused by the following:

- Ignition coil shorted to ground and arcing at plugs.
- MIL circuit to GCP shorted to ground.
- Poor GCP grounds.

Symptom Charts

NOTE: If you have a symptom of the pedal not working, and no DTC is set, go to the voltage screen and check pedal voltage. If pedal voltage is.75-1.25 volts, and idle validation switch says you're at idle - replace the pedal.

Engine Performance - No Load

NOTE: Items listed in the possible cause column generally do not set a diagnostic trouble code (DTC) or illuminate the MIL light.

NOTE: EDI engines are used in many different applications and equipment. When performing any system diagnosis be aware of any OEM inputs or equipment monitoring devices that may have an effect on the engine's performance or any of the engine's operating systems.

SYMPTOM	POSSIBLE CAUSE
Engine Runs Briefly and Shuts Down	• Loss of Spark • Frozen Fuel Regulator (Dry Fuel) • Low Fuel Pressure • Air Inlet Restriction • Wiring Failure • GCP Failure
Engine Cranks But No Start	• Faulty OEM Drivers Safety Shut-Off Seat Switch • Coil Power Loss • GCP Ground Loss • GCP Power Loss • Severe Vacuum Leak (Dry Fuel) • Air Inlet Restriction • Air Inlet Leak (Dry Fuel) • Fuel Lock-Off Inoperative (Dry Fuel) • Wiring Failure • Low Fuel Pressure • Ancillary Components Binding
Engine Runs Poorly	• High Fuel Pressure • Low Fuel Pressure • Contaminated Fuel • Incorrect Fuel Select Table Selected • Wrong GCP Installed • Actuator Air Blockage • Map Sensor Leak • Fuel Contaminated • Noise Suppression Capacitor Failure • Improper PCV Routing • Valve Timing • Low Cylinder Compression
Engine Cranks Slowly	• Excessive Engine Load (Hydraulic Pump Failing, Binding Ancillary Drive Components)\ • Low Battery Voltage • Incorrect Battery Specifications • Incorrect Battery Cable Size • Starter Relay • Starter Failure (Excessive Drain)
Engine Does Not Crank	• Dead Battery • Ground Loss • Ancillary Components Binding or Seized • OEM Shutdown - Oil Level Safety • Starter Lockout Relay Failure • Ignition Switch Failure • Bad Starter • Crank Control Wire Failure • Loose Connection or Corrosion

Engine Performance - While Under Load

SYMPTOM	POSSIBLE CAUSE
Engine Stalls/Quits	• Faulty OEM Drivers Safety Shut-off Seat Switch • Low Battery Voltage • Low Fuel Pressure • OEM Safety Shutdowns • Bad MAP Sensor • Air Restriction • Coil Failure • Fuel Mixer Binding (Dry Fuel)
Runs Rough	• Ground Loss • Misrouted Spark Plug Wires • Fuel System Failure • Vacuum Leak • Wiring Failure • Low Fuel Pressure • Spark Plugs Fouled • Incorrect Valve Timing
Misses	• Fuel System Failure • Misrouted Spark Plug Wires • Spark Plug Gap Too High • Spark Plugs Fouled • Cracked Spark Plug Insulator • Incorrect Valve Timing • Compression Loss
Hesitation/Stumble	• Low Fuel Pressure • Spark Plugs Fouled • MAP Sensor Vacuum Signal Loss
Surge	• Low Fuel Pressure • Map Sensor Failure • Application or Ancillary System Momentarily Binding During Load or Unload
Backfires	• Faulty OEM Drivers Safety Shut-off Seat Switch • Fouled Spark Plugs • Spark Plug Wire Broke • GCP Momentary Ground Loss • Excess Lean Condition • Fuel Lock-Off Leaking (Dry Fuel) • Intake Manifold Leak • Bad Intake Valve
Lack of Power	• Ancillary Components Binding • Intake Air Restriction • Crossed Spark Plug Wires • Spark Plugs Fouled • Fuel System Failure • Low Fuel Pressure • Low Cylinder Compression
Spark Knock	• Poor Quality or Contaminated Fuel • Carbon Build-up • Wrong Spark Plugs (Too High Heat Range) • Fuel Delivery System • PCV System • Fuel Selection Timing • Cylinder Hot Spots

Engine Concerns

SYMPTOM	POSSIBLE CAUSE
Oil System Concerns **- High Oil Consumption**	• Positive Crankcase Ventilation (PCV) System • Oil Viscosity • External Leaks • Improper Oil Dipstick • Valve Seals • Cylinder Wall Taper Excessive • Worn Piston Rings
Cooling System Concerns	• Trapped Air • Worn Drive Belt • Worn Water Pump • Stuck Thermostat • Plugged Radiator (Internal & External) • Dry Fuel System Running Rich
Exhaust System Concerns (visible smoke) **- Black Smoke** **- Blue Smoke**	 • Ignition System • Fuel Delivery System • Sticking Fuel Injector • High Fuel Pressure • PCV System • Worn Piston Rings • Worn valve guides
Fuel System Concerns	• Leaky Lines • Contaminated Fuel • Excessive Alcohol in Fuel • Incorrect Octane Rating
Engine Noise	• Low Oil Pressure • Oil Filter Restriction

Engine Control Module (GCP) – Diagnostic Trouble Codes

CAUTION: When checking codes with the diagnostic software, the DTC terminal can NOT be grounded.

CAUTION: Removing battery power before accessing diagnostic program will erase all codes recorded.

This section contains circuit description information and troubleshooting charts on all the DTC's obtained by diagnostic software or a Malfunction Indicator Lamp (MIL). When diagnostic trouble codes are obtained by a Malfunction Indicator Lamp (MIL), the following sequence will be flashed:

- 123 will flash 3 times to indicate the beginning of the flash code display sequence.
- Any active DTC's will flash 3 times each.
- 123 will flash 3 times indicating the end of the code display sequence.

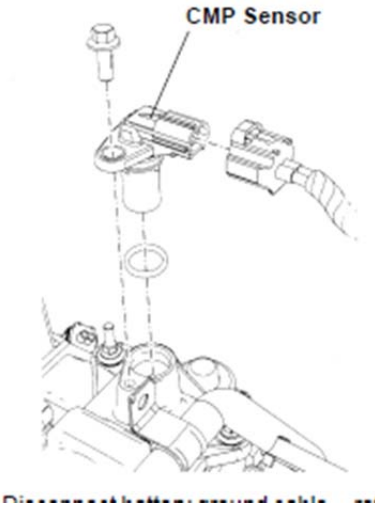
If code 123 is the only code present, the system does not have any active codes - all systems are working fine.

If an active DTC is present, refer to the GCP diagnostic manual for code description and troubleshooting.

NOTE: If you have a symptom of the pedal not working, and no DTC is set, go to the voltage screen and check pedal voltage. If pedal voltage is .75 - 1.25 volts, and idle validation switch says you're at idle – replace the pedal.

REMOVAL AND INSTALLATION

Camshaft Position (CMP) Sensor - Replacement



1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the CMP Sensor.
3. Disconnect CMP electrical connector.
4. Remove bolt and CMP Sensor.
5. Reverse procedure to install:
    - Use a new o-ring seal
    - Lubricate o-ring with clean engine oil prior to installation
    - Tighten bolt to 7 Nm (62 lb-in).

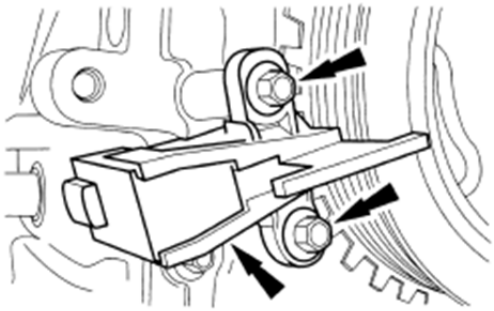
Crankshaft Position (CKP) Sensor - Removal

1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the CKP Sensor.

3. Disconnect CKP electrical connector.
4. Remove plug.

Crankshaft Position (CKP) Sensor - Installation

1. Position CKP sensor and loosely install the bolt.



2. Adjust the CKP sensor with the alignment tool and tighten 2 bolts.
    - Tighten to 7 Nm (62 lb-in).
3. Connect CKP sensor electrical connector

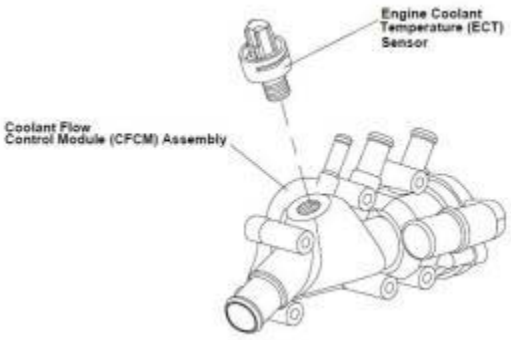
Engine Coolant Temperature (ECT) Sensor- Replacement

NOTE: Removal steps in this procedure may contain installation details.

1. Disconnect battery ground cable -- refer to section 6

NOTE: The sensor is located at the rear of the cylinder head.

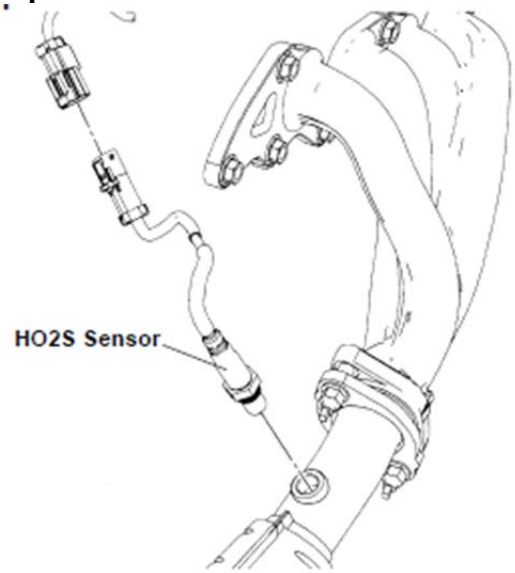
1. **NOTE:** Lubricate the O-ring seal with clean engine oil.
    - Torque: 30 Nm



Installation

1. To install, reverse the removal procedure.

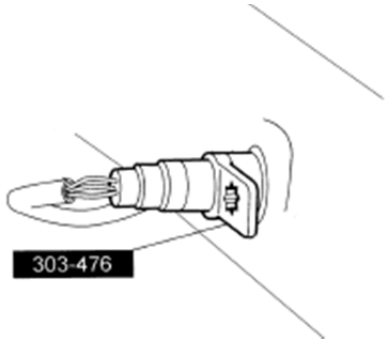
Heated Oxygen Sensor (HO2S) - Replacement



2. Disconnect battery ground cable -- refer to section 6
3. Remove or disconnect any component to allow access and removal of the HO2S Sensor.
4. Disconnect HO2S electrical connector.

NOTE: Use penetrating oil to assist in removal.

5. Remove HO2S sensor.



6. Reverse procedure to install:
    - Apply a light coat of anti-seize lubricant to the threads of the sensor.
    - Tighten sensor to 40 Nm (30 lb-ft).

Knock Sensor (KS) – Replacement

1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the knock sensor.
3. Disconnect KS sensor electrical connector.

NOTE: The KS sensor is a one-time use item and a new KS sensor must be installed.

4. Remove bolt and KS sensor and discard sensor.
5. Reverse procedure to install:
    - Install a new KS sensor
    - Tighten bolt to 20 Nm (15 lb-ft).

Temperature Manifold Absolute Pressure (TMAP) Sensor - Replacement

1. Disconnect battery ground cable -- refer to section 6.
2. Remove or disconnect any component to allow access and removal of the TMAP sensor.
3. Disconnect TMAP electrical connector.
4. Remove bolt and TMAP Sensor.
5. Reverse procedure to install:
    a. Use a new o-ring seal
    b. Tighten bolt to 3 Nm (2.2 lb-ft).

Actuator/Throttle Position (TP) Sensor - Replacement

Removal

NOTE: Removal steps in this procedure may contain installation details.

1. Disconnect battery ground cable -- refer to section 6
2. Disconnect the connector from the throttle
3. Remove the bolts from the throttle to the intake manifold
4. **NOTE:** The gasket is to be reused unless damaged.

Installation

1. To install, reverse the removal procedure.
    - Torque bolts to 10 Nm

2. The gasket between the throttle and intake manifold is to be reused unless damaged.

TSG-416 METRICS

INDEX

Subject	Page
Introduction	09 - 2
Nomenclature for Bolts	09 – 2
Bolt Strength Identification	09 – 3
Hex Nut Strength Identification	09 – 3
Other Types of Parts	09 – 4
English/Metric conversion	09 – 5
Decimal and Metric Equivalents	09 – 6
Torque Conversion	09 – 6
J1930 Terminology List	09 - 7

TSG-416 METRICS

INTRODUCTION

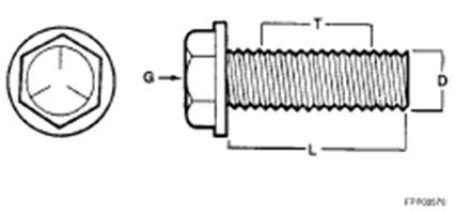
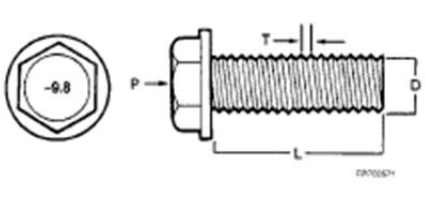
Most threaded fasteners are covered by specifications that define required mechanical properties, such as tensile strength, yield strength, proof load and hardness. These specifications are carefully considered in initial selection of fasteners for a given application. To ensure continued satisfactory vehicle performance, replacement fasteners used should be of the correct strength, as well as the correct nominal diameter, thread pitch, length, and finish.

Most original equipment fasteners (English or Metric system) are identified with markings or numbers indicating the strength of the fastener. These markings are described in the pages that follow. Attention to these markings is important to ensure that the proper replacement fasteners are used.

Further, some metric fasteners, especially nuts, are colored blue. This metric blue identification is in most cases a temporary aid for production start-up, and color will generally revert to normal black or bright after start-up.

English or Metric system fasteners are available through your Ford Parts and Service operation.

NOMENCLATURE FOR BOLTS

English System Bolt, 1/2 - 13 x 1	Metric System Bolt, M12 - 1.75 x 25
	
G = Grade Marking (bolt strength) L = Length (inches) ** T = Thread Pitch (thread/inch) D = Nominal Diameter (inches)	P = Property Class (bolt strength) * L = Length (millimeters) ** T = Thread Pitch (thread width crest to crest mm) D = Nominal Diameter (millimeters)

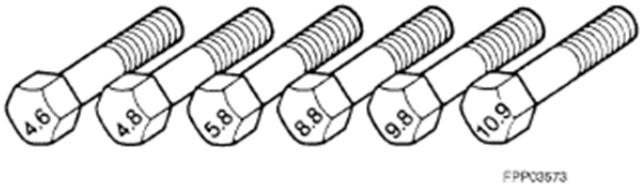
* The Property class is an Arabic numeral distinguishable from the slash SAE English grade system.
** The length of all bolts is measured from the underside of the head to the end.

BOLT STRENGTH IDENTIFICATION

English System

English (inch) bolts: Identification marks correspond to bolt strength, increasing number of slashes represent increasing strength.

Metric System



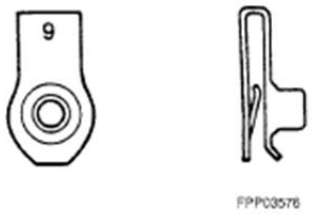
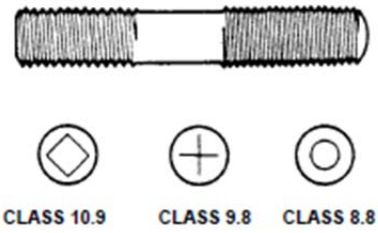
Metric (mm) bolts: Identification class numbers correspond to bolt strength, increasing numbers represent increasing strength. Common metric fastener bolt strength properties are 9.8 and 10.9 with the class identification embossed on the bolt head.

HEX NUT STRENGTH IDENTIFICATION

English System - Grade Identification	Metric System - Class Identification
HEX NUT Grade 5 (3 dots) HEX NUT Grade 8 (6 dots) FPP03574	HEX NUT Property Class 9 (Arabic 9) HEX NUT Property Class 10 (Arabic 10) FPP03575
Increasing dots represent increasing strength.	May also have blue finish or paint daub on hex flat. Increasing numbers represent increasing strength.

OTHER TYPES OF PARTS

Metric identification schemes vary by type of part, most often a variation of that used of bolts and nuts. Note that many types of English and Metric fasteners carry no special identification if they are otherwise unique.

Stamped U-Nuts	 FPP03576
Tapping, thread forming and certain other case hardened screws	FPP03577
Studs, Large studs may carry the property class number. Smaller studs use a geometric code on the end.	 FPP03578

TSG-416 METRICS

ENGLISH/METRIC CONVERSION

TO CONVERT FROM TO	TO FROM	MULTIPLY BY DIVIDE BY
Distance		
inches	mm	25.4
inches	m	0.0254
feet	mm	304.8
feet	m	0.3048
yards	m	0.9144
mile	km	1.609
Area		
in^2	mm^2	645.16
$ft.^2$	m^2	0.0929
$ft.^2$	cm^2	6.45
yds^2	m^2	0.8361
Volume		
in^3	cm^3	16.3871
in^3	mm^3	16387.0
in^3	1 liter	0.016387
$yard^3$	m^3	0.7646
pint (us)	1 liter	0.47318
pint (uk)	1 liter	0.56826
quart (us)	1 liter	0.94635
gallon (us)	1 liter	3.7854
gallon (uk)	1 liter	4.5461
$ft.^3$	1 liter	28.3168
$ft.^3$	m^3	0.02832
Mass		
oz.	g	28.3495
lb.	kg	0.45359
ton	kg	907.18
ton (US)	tonne	0.90718
ton (UK)	tonne	1.01605
Density		
Force		
lbf	Newton (N)	4.44822
kilogram	Newton (N)	9.807
ounce	Newton (N)	0.2780
Pressure & Stress		
1000 kpa	Bar	1000
lbf/in^2 (psi)	kPa	6.895
lbf/in^2 (psi)	N/M^2	6894.76
lbf/in^2 (psi)	Bar	0.0689
lbf/in^2 (psi)	N/mm^2	0.00689
lbf/m^2 (psi)	mmHg	51.715
"H2O	kPa	0.2491
"H2O	mmH2O	25.4
"Hg	mmHG	25.4
ton (US)/in^2	N/mm^2	13.7894
ton (UK)/in^2	N/mm^2	15.4443
Velocity		
ft./sec.	m/s	0.3048
ft./sec.	km/h	1.09728
miles/h	m/s	0.44694
miles/h	km/h	1.609
Acceleration		
in./sec^2	m/s^2	0.0254
ft./sec^2	m/s^2	0.3048
Light		
foot candle	lumens/sq meter	10.764

TO CONVERT FROM TO	TO FROM	MULTIPLY BY DIVIDE BY
Energy		
kW.h	Joules (J)	3,600,000
lb/ft	Joules (J)	1.3558
Btu	Joules (J)	1055.06
Kcal	Joules (J)	4186.8
HP.h	kW.h	0.7457
PS.h	kW.h	0.7355
Temperature		
degree Farenheit (°F)	degree Celsius (°C)	(°F-32) x 0.556
Torque		
lb./ft.	Nm	1.35582
lb./in.	Nm	0.11298
Power		
HP	kW	0.7457
PS	kW	0.7355
HP	PS	1.01387
Specific Fuel Consumption		
lb./hp.h	g/kW.h	608.277
miles/gal	kilometers/liter (km/L)	0.4251
gal/miles	liters/kilometer (L/km)	2.3527

TSG-416 METRICS

DECIMAL AND METRIC EQUIVALENTS

FRACTIONS	DECIMAL INCH	METRIC MM
1/64	.01562S	.397
1/32	.0312S	.794
3/64	.04687S	1.191
1/16	.062S	1.588
5/64	.07812S	1.984
3/32	.09375	2.381
7/64	.10937S	2.778
1/8	.125	3.175
9/64	.14062S	3.572
5/32	.1562S	3.969
11/64	.17187S	4.366
3/16	.1875	4.763
13/64	.20312S	5.159
7/32	.21875	5.556
15/64	.23437S	5.953
1/4	.250	6.35
17/64	.26562S	6.747
9/32	.2812S	7.144
19/64	.29687S	7.54
5/16	.3125	7.938
21/64	.32812S	8.334
11/32	.3437S	8.731
23/64	.35937S	9.128
3/8	.375	9.525
25/64	.39062S	9.922
13/32	.4062S	10.319
27/64	.42187S	10.716
7/16	.4375	11.113
29/64	.45312S	11.509
15/32	.4687S	11.906
31/64	.48437S	12.303
1/2	.500	12.7
33/64	.51562S	13.097
17/32	.5312S	13.494
35/64	.54687S	13.891
9/16	.5625	14.288
37/64	.57812S	14.684
19/32	.5937S	15.081
39/64	.60937S	15.478
5/8	.625	15.875
41/64	.64062S	16.272
21/32	.6562S	16.669
43/64	.67187S	17.066
11/16	.6875	17.463
45/64	.70312S	17.859
23/32	.7187S	18.256
47/64	.73437S	18.653
3/4	.750	19.05
49/64	.76562S	19.447
25/32	.7812S	19.844
51/64	.79687S	20.241
13/16	.8125	20.638
53/64	.82812S	21.034
27/32	.8437S	21.431
55/64	.85937S	21.828
7/8	.875	22.225
57/64	.89062S	22.622
29/32	.9062S	23.019
59/64	.92187S	23.416
15/16	.9375	23.813
61/64	.95312S	24.209
31/32	.9687S	24.606
63/64	.98437S	25.003
1	1.00	25.4

TORQUE CONVERSION

Newton Meters (Nm)	Pound Feet (lb-ft)
1	0.7376
2	1.5
3	2.2
4	3.0
5	3.7
6	4.4
7	5.2
8	5.9
9	6.6
10	7.4
15	11.1
20	14.8
25	18.4
30	22.1
35	25.8
40	29.5
50	36.9
60	44.3
70	51.6
80	59.0
90	66.4
100	73.8
110	81.1
120	88.5
130	95.9
140	103.3
150	110.6
160	118.0
170	125.4
180	132.8
190	140.1
200	147.5
225	166.0
250	184.4

Newton Meters (Nm)	Pound Feet (lb-ft)
1	1.356
2	2.7
3	4.0
4	5.4
5	6.8
6	8.1
7	9.5
8	10.8
9	12.2
10	13.6
15	20.3
20	27.1
25	33.9
30	40.7
35	47.5
40	54.2
45	61.0
50	67.8
55	74.6
60	81.4
65	88.1
70	94.9
75	101.7
80	108.5
90	122.0
100	135.6
110	149.1
120	162.7
130	176.3
140	189.8
150	203.4
160	216.9
170	230.5
180	244.0

J1930 TERMINOLOGY LIST

Certain Ford Component names have been changed in this Service Manual to conform to Society of Automotive Engineers (SAE) directive J1930.

SAE J1930 standardizes automotive component names for all vehicle manufacturers.

New Term	New Acronym	Old Terms (Acronyms)
Accelerator Pedal	AP	Accelerator
Air Cleaner	ACL	Thermac Air Cleaner
Air Cleaner Element	ACL Element	Air Cleaner Element (ACL Element)
Air Cleaner Housing	ACL Housing	Air Cleaner Housing (ACH)
Air Cleaner Housing Cover	ACL Housing Cover	Air Cleaner Housing Cover (ACL Housing Cover)
Air Conditioning	A/C	Air Conditioning (AC)
Air Conditioning Clutch	A/C Clutch	Air Conditioning Clutch (ACC)
Air Conditioning Cycling Switch	A/C Cycling Switch	Air Conditioning Cycling Switch (ACCS)
Air Conditioning Sensor	A/C Sensor	Air Conditioning Sensor (A/C Sensor)
Air Conditioning System	A/C System	Air Conditioning System (SCS)
Automatic Transaxle	A/T	Electronic Automatic Transaxle (EATX)
Automatic Transmission	A/T	Electronic Automatic Transmission (EATX)
Barometric Pressure	BARO	Barometric Pressure (BARO)
Barometric Pressure Sensor	BARO Sensor	- Absolute Pressure Sensor (APS) - Barometric Pressure Sensor (BP Sensor
Battery Positive Voltage	B+	Battery Positive Voltage (B+)
Camshaft Position	CMP	Sync Pickup
Camshaft Position Sensor	CMP Sensor	- Camshaft Position Sensor (CPS) - Camshaft Sensor - Cylinder Identification Sensor (Cylinder ID Sensor) (CID)
Canister	Canister	Canister
Carburetor	CARB	Feed Back Carburetor (FBC)
Central Multiport Fuel Injection	Central MFI	- Central Multiport Fuel Injection (CMFI) - Fuel Injection (FI)
Charge Air Cooler	CAC	- After Cooler - Inter Cooler
Closed Loop	CL	Closed Loop System (CLS)
Closed Throttle Position	CTP	Closed Throttle Position (CTP)
Closed Throttle Position Switch	CTP Switch	Closed Throttle Switch
Clutch Pedal Position	CPP	Clutch Pedal Position (CPP)
Clutch Pedal Position Switch	CPP Switch	- Clutch Engage Switch (CES) - Clutch Start Switch - Clutch Switch
Compact Disc Read Only memory	CDROM	Compact Disc Read Only Memory (CDROM)

TSG-416 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Continuous Fuel Injection	CFI	- Continuous Injection System (CIS) - Continuous Injection System - Electronic (continuous Injection System-E) (CIS-E) - Fuel Injection (FI) - K-Jetronic - KE-Jetronic - KE-Motronic
Continuous Fuel Injection system	CFI System	Continuous Injection System (CIS)
Continuous Trap Oxidizer	CTOX	- Continuous Trap Oxidizer (CTO) - Trap Oxidizer - Continuous (TOC)
Crankshaft Position	CKP	- Crankshaft Position (CP) - Position Indicator Pulse (PIP)
Crankshaft Position Sensor	CKP Sensor	- Crankshaft Position Sensor (CPS) - Crank Angle Sensor
Data Link Connector	DLC	- Assembly Line Communication Link (ALCL) - Assembly Line Diagnostic Link (ALDL) - Self Test Connector - Vehicle in Process Connector (VIP Connector)
Diagnostic Test Mode	DTM	Modes
Diagnostic Trouble Code	DTC	Self Test Codes
Differential Pressure Feedback Gas Recirculation System	Differential Pressure Feedback EGR System	Differential Pressure Feedback EGR System
Direct Fuel Injection	DFI	- Direct Injection (DI) - Direct Injection - Diesel (DID) - Fuel Injection (FI)
Distributor Ignition	DI	- Capacitive Discharge Ignition (CDI) - Closed Bowl Distributor - Electronic Ignition (EI) (with Distributor) - Electronic Spark Advance Control (ESAC) - High Energy Ignition (HEI) - Remote Mount Thick Film Ignition (Remote Mount TFI) - Thick Film Ignition (TFI)
Distributor Ignition Capacitor	DI Capacitor	Condenser
Distributor Ignition Control Module	Distributor ICM	Electronic Distributor Ignition System Module (EDIS Module)
Distributor Ignition System	DI System	Electronic Distributor Ignition System (EDIS)
Early Fuel Evaporation	EFE	Early Fuel Evaporation (EFE)
Electrically Erasable Programmable Read Only Memory	EEPROM	Electrically Erasable Programmable Read Only Memory (E2PROM)
Electronic Continuous Fuel Injection System	Electronic CFI System	Continuous Injection System - Electronic (Continuous Injection System-E) (CIS-E)
Electronic engine Control	Electronic EC	Electronic Engine Control (EEC)
Electronic Ignition	EI	- Computer Controlled Coil Ignition (C3I) - Distributorless Ignition (DLI) - Electronic Ignition (EI) (without distributor) - Integrated Direct Ignition (IDI)
Electronic Ignition System	EI System	- Direct Ignition System (DIS) - Distributorless Ignition System (DIS) - Electronic Distributorless Ignition System (EDIS)
Engine Control	EC	Electronic Engine Control (EEC)
Engine Control Module	ECM	Engine Control Module (ECM)

TSG-416 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Engine Coolant Level	ECL	Engine Coolant Level (ECL)
Engine Coolant Level Indicator	ECL Indicator	Engine Coolant Level Indicator
Engine Coolant Temperature	ECT	Engine Coolant Temperature (ECT)
Engine Coolant Temperature Sensor	ECT Sensor	- Coolant Temperature Sensor (CTS) - Engine Coolant Temperature Sender (ECT Sender)
Engine Coolant Temperature Switch	ECT Switch	Coolant Temperature Switch (CTS)
Engine Speed	RPM	- Crankshaft Speed - Revolutions Per Minute (RPM)
Engine Speed Sensor	RPM Sensor	Crankshaft Speed Sensor
Erasable Programmable Read Only Memory	EPROM	Erasable Programmable Read Only Memory (EPROM)
Evaporative Emission	EVAP	Evaporative Emission (EVAP)
Evaporative Emission Canister	EVAP Canister	- Canister - Charcoal Canister
Evaporative Emission Canister Purge	EVAP Canister Purge	- EVAP CANP - Canister Purge (CANP)
Evaporative Emission Canister Purge Valve	EVAP Canister Purge Valve	- Canister Purge Valve - Canister Purge Vacuum Switching Valve (Canister Purge VSV) - Duty Solenoid for Purge Valve - Evaporative Emission Purge Valve (EVAP Purge Valve) - Vacuum Solenoid Valve (Canister) (VSV) - Vacuum Solenoid Valve (EVAP) (VSV)
Evaporative Emission System	EVAP System	Evaporation Emission Control System (EECS)
Exhaust Gas Recirculation	EGR	Digital Exhaust Gas Recirculation (Digital EGR)
Exhaust Gas Recirculation Backpressure Transducer	EGR Backpressure Transducer	Backpressure Transducer
Exhaust Gas Recirculation Diagnostic Valve	EGR Diagnostic	EGR Diagnostic Valve
Exhaust Gas Recirculation System	EGR System	EGR System
Exhaust Gas Recirculation Temperature	EGRT	EGR Temperature
Exhaust Gas Recirculation Temperature Sensor	EGRT Sensor	Recirculated Exhaust Gas Temperature Sensor (REGTS)
Exhaust Gas Recirculation Thermal Vacuum Valve	EGR TVV	EGR Thermal Vacuum Valve (EGR TVV)
Exhaust Gas Recirculation Vacuum Regulator Solenoid	EGR Vacuum Regulator Solenoid	EGR Vacuum Regulator Solenoid (EVR Solenoid)
Exhaust Gas Recirculation Vacuum Regulator Valve	EGR Vacuum Regulator Valve	EGR Vacuum Regulator Valve (EVRV)
Exhaust Gas Recirculation Valve	EGR Valve	EGR Valve (EGRV)
Exhaust Gas Recirculation Valve Control	EGR Valve Control	EGR Valve Control (EGRVC)
Exhaust Gas Recirculation Valve Position Sensor	EGR Valve Position Sensor	EGR Valve Position Sensor (EVP Sensor)
Fan Control	FC	- Electro-Drive Fan Control (EDF Control) - Engine Coolant Fan Control - High Electro-Drive Fan Control (HEDF Control) - Radiator Fan Control
Fan Control Module	FC Module	Fan Control Module

TSG-416 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Fan Control Relay	FC Relay	- Fan Motor Control Relay - Radiator Fan Relay
Feedback Pressure Exhaust Gas Recirculation	Feedback Pressure EGR	Pressure Feedback Exhaust Gas Recirculation
Feedback Pressure Exhaust Gas Recirculation Sensor	Feedback Pressure EGR Sensor	Pressure Feedback Exhaust Gas Recirculation (PFE) Sensor
Flash Electrically Erasable Programmable Read Only Memory	FEEPROM	Flash EEPROM
Flash Erasable Programmable Read Only Memory	FEPROM	Flash EPROM
Flexible Fuel	FF	Flexible Fuel (FF)
Flexible Fuel Sensor	FF Sensor	- Alcohol Concentration Sensor - Fuel Concentration Sensor - Fuel Quality Sensor - Percent Alcohol Sensor - Variable Fuel Sensor
Forth Gear	4GR	Fourth Gear (4GR)
Fuel Level Sensor	Fuel Level Sensor	Fuel Sensor
Fuel Pressure	Fuel Pressure	Fuel Pressure
Fuel Pressure Regulator	Fuel Pressure Regulator	Fuel Regulator
Fuel Pump	FP	Fuel Pump (FP)
Fuel Pump Module	FP Module	- Fuel Module - Fuel Sender - Fuel Tank Unit - In Tank Module
Fuel Pump Relay	FP Relay	Fuel Pump Relay
Fuel Trim	FT	Adaptive Fuel Strategy
Generator	GEN	Alternator (ALT)
Governor	Governor	Governor
Governor Control Module	GCM	Governor Electronic Module (GEM)
Ground	GND	Ground (GRD)
Heated Oxygen Sensor	HO2S	- Heated Exhaust Gas Oxygen Sensor (HEGO Sensor) - Heated Oxygen Sensor (HOS)
High Speed Fan Control Switch	High Speed FC Switch	High speed Fan Control Switch (High Speed FC Switch)
Idle Air Control	IAC	- Idle Air Bypass Control - Idle speed Control (ISC) - Idle Speed Control Bypass air (ISC BPA)
Idle Air Control Thermal Valve	IAC Thermal Valve	Fast Idle Thermo Valve
Idle Air Control Valve	IAC Valve	- Air Valve - Fast Idle Thermo Valve - Idle Air Control Valve (IACV)
Idle Speed Control	ISC	Throttle Opener
Idle Speed Control Actuator	ISC Actuator	Idle Speed Control Actuator (ISC Actuator)
Idle Speed Control Solenoid Vacuum	ISC Solenoid Vacuum Valve	- Throttle Opener Vacuum Switching Valve (Throttle Opener VSV) - Vacuum Solenoid Valve (Throttle) (VSV)

TSG-416 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Ignition Control	IC	- Electronic Spark Advance (ESA) - Electronic spark Timing (EST)
Ignition Control Module	ICM	- Distributorless Ignition System Module (DIS Module) - Thick Film Ignition Module (TFI Module)
Indirect Fuel Injection	IFI	- Fuel Injection (FI) - Indirect Fuel Injection (IDFI) - Indirect Diesel Injection (IDI)
Inertia Fuel Shutoff	IFS	Inertia Fuel Shutoff (IFS)
Inertia Fuel Shutoff Switch	IFS Switch	- Inertia Switch - Inertia Fuel - Shutoff Switch
Intake Air	IA	Intake Air
Intake Air Duct	IA Duct	Intake Air Duct
Intake Air System	IA System	Air Intake System
Intake Air Temperature	IAT	- Air Charge Temperature (ACT) - Manifold Air Temperature (MAT) - Throttle Body Temperature (TBT) - Vane Air Temperature (VAT)
Intake Air Temperature Sensor	IAT Sensor	- Air Temperature Sensor (ATS) - Intake Air Temperature Sensor (IATS) - Manifold Air Temperature Sensor (MATS)
Keep Alive Random Access Memory	Keep Alive RAM	Keep Alive memory (KAM)
Knock Sensor	KS	Detonation Sensor (DS)
Long Term Fuel Trim	Long Term FT	- Block Learn Matrix (BLM) - Block Learn Memory (BLM) - Block Learn Multiplier (BLM)
Low Speed Fan Control Switch	Low Speed FC Switch	Low Speed Fan Control Switch (Low Speed FC Switch)
Malfunction Indicator Lamp	MIL	- Check Engine - Service Engine Soon
Manifold Absolute Pressure	MAP	Manifold Absolute Pressure (MAP)
Manifold Absolute Pressure Sensor	MAP Sensor	- Intake Manifold Absolute Pressure Sensor - Manifold Absolute Pressure Sensor (MAPS) - Pressure Sensor (P-Sensor)
Manifold Differential Pressure	MDP	Manifold Differential Pressure (MDP)
Manifold Differential Pressure Sensor	MDP Sensor	Vacuum Sensor (VAC Sensor)
Manifold Surface Temperature	MST	Manifold Surface Temperature (MST)
Manifold Vacuum Zone	MVZ	Manifold Vacuum Zone (MVZ)
Manifold Vacuum Zone Switch	MVZ Switch	Vacuum Switches
Mass Air Flow	MAF	- Air Flow Control (AFC) - Air Flow Meter
Mass Air Flow Sensor	MAF Sensor	- Air Flow Meter - Air Flow Sensor (AFS) - Hot Wire Anemometer
Mixture Control	MC	- Feed Back Control (FBC) - Mixture Control (M/C)
Mixture Control Solenoid	MC Solenoid	Mixture Control Solenoid (MCS)

TSG-416 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Multiport Fuel Injection	MFI	- D-Jetronic - Digital Fuel Injection (EFI) - Electronic Fuel Injection (EFI) - Fuel Injection (FI) - L-Jetronic - LH-Jetronic - Motronic - Multipoint Injection (MPI) - Multiport Injection (MPI) - Port Fuel Injection (PFI) - Programmed Fuel Injection (PGM-FI) - Tuned Port Injection (TPI)
Nonvolatile Random Access Memory	NVRAM	- Keep Alive Memory (KAM) - Nonvolatile Memory (NVM)
Oil Pressure Sensor	Oil Pressure Sensor	Oil Pressure Sender
Oil Pressure Switch	Oil Pressure Switch	Oil Pressure Switch
On-Board Diagnostic	OBD	Self Test
Open Loop	OL	Open Loop (OL)
Oxidation Catalytic Converter	OC	- Continuous Oxidation Catalyst (COC) - Oxidation Catalyst (OC)
Oxygen Sensor	O2S	- Exhaust Gas Oxygen Sensor (EGO Sensor, EGOS) - Exhaust Gas Sensor (EGS) - Exhaust Oxygen Sensor (EOS) - Lambda - Oxygen Sensor (O2 Sensor, OS)
Park/Neutral Position	PNP	Park/Neutral (P/N)
Park/Neutral Position Switch	PNP Switch	- Neutral Drive Switch (NDS) - Neutral Gear Switch (NGS) - Neutral Position Switch (NPS) - Neutral Safety Switch
Periodic Trap Oxidizer	PTOX	Trap Oxidizer - Periodic (TOP)
Positive Crankcase Ventilation	PCV	Positive Crankcase Ventilation (PCV)
Positive Crankcase Ventilation (Valve)	PCV Valve	Positive Crankcase Ventilation (PCV valve)
Power Steering Pressure	PSP	Power Steering Pressure (PSP)
Power Steering Pressure Switch	PSP Switch	Power Steering Pressure Switch (P/S Pressure Switch, PSPS)
Powertrain Control Module	PCM	- Electronic Control Assembly (ECA) - Electronic Control Unit 4 (ECU4) - Electronic Engine Control Processor (EEC Processor) - Microprocessor Control Unit (MCU) - Single Board Engine Control (SBEC) - Single Module Engine Control (SMEC)
Pressure Transducer Exhaust Gas Recirculation System	Pressure Transducer EGR System	Pressure Transducer EGR System
Programmable Read Only Memory	PROM	Programmable Read Only memory (PROM)
Pulsed Secondary Air Injection	PAIR	- Air Injection Reactor (AIR) - Air Injection Valve (AIV) - Pulsair - Thermactor II
Pulsed Secondary Air Injection Valve	PAIR Valve	Reed Valve
Random Access Memory	RAM	Random Access Memory (RAM)
Read Only memory	ROM	Read Only Memory (ROM)

TSG-416 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Relay Module	RM	Integrated Relay Module
Scan Tool	ST	Scan Tool
Secondary Air Injection	AIR	- Air Injection (AI) - Air Injection Reactor (AIR) - Thermac - Thermactor
Secondary Air Injection Bypass	AIR Bypass	- Air Management 1 (AM1) - Secondary Air Injection Bypass (AIRB) - Thermactor Air Bypass (TAB)
Secondary Air Injection Bypass Valve	AIR Bypass Valve	Secondary Air Bypass Valve (SABV)
Secondary Air Injection Check Valve	AIR Check Valve	Secondary Air Check Valve
Secondary Air Injection Control Valve	AIR Control Valve	- Air Control Valve - Secondary Air Check Valve (SACV)
Secondary Air Injection Diverter	AIR Diverter	- Air Management2 (AM2) - Secondary Air Injection Diverter (AIRD) - Thermactor Air Diverter (TAD)
Secondary Air Injection Pump	AIR Pump	Air Injection Pump (AIP)
Secondary Air Injection Switching Valve	AIR Switching Valve	Secondary Air Switching Valve (SASV)
Sequential Multiport Fuel Injection	SFI	- Fuel Injection (FI) - Sequential Electronic Fuel Injection (SEFI) - Sequential Fuel Injection (SFI)
Service Reminder Indicator	SRI	- Check Engine - Engine Maintenance Reminder (EMR) - Oxygen Sensor Indicator (OXS) - Service Engine Soon
Short Term Fuel Trim	Short Term FT	Integrator (INT)
Smoke Puff Limiter	SPL	Smoke Puff Limiter (SPL)
Supercharger	SC	Supercharger (SC)
Supercharger Bypass	SCB	Supercharger Bypass (SCB)
Supercharger Bypass Solenoid	SCB Solenoid	Supercharger Bypass Solenoid (SBS)
System Readiness Test	SRT	System Readiness Test (SRT)
Thermal Vacuum Valve	TVV	Thermal Vacuum Switch (TVS)
Third Gear	3GR	Third Gear (3GR)
Three Way Catalytic Converter	TWC	Three Way Catalytic Converter (TWC)
Three Way + Oxidation Catalytic Converter	TWC + OC	Dual Bed
Throttle Body	TB	Fuel Charging Station
Throttle Body Fuel Injection	TBI	- Central Fuel Injection (CFI) - Electronic Fuel Injection (EFI) - Fuel Injection (FI) - Monotronic - Single Point Injection (SPI)
Throttle Position	TP	Throttle Position (TP)
Throttle Position Sensor	TP Sensor	- Throttle Position Sensor (TP) - Throttle Potentiometer
Throttle Position Switch	TP Switch	Throttle Position Switch (TPS)
Torque Converter Clutch	TCC	- Converter Clutch Control (CCC) - Converter Clutch Override (CCO) - Viscous Converter Clutch (VCC)

TSG-416 METRICS

New Term	New Acronym	Old Terms (Acronyms)
Torque Converter Clutch Relay	TCC Relay	Lock Up Relay
Torque Converter Clutch Solenoid Valve	TCC Solenoid Valve	Lock Up Solenoid Valve (LUS)
Transmission Control Module	TCM	Transmission Control Module
Transmission Range	TR	- Park, Reverse, Neutral, Drive, Low (PRNDL) - Selection Lever Position (SLP) - Transmission Range Selection (TRS)
Transmission Range Sensor	TR Sensor	Manual Lever Position Sensor (MLP Sensor)
Transmission Range Switch	TR Switch	- Manual Range Position Switch (MRPS) - Transmission Position Switch - Transmission Range Selection Switch (TRSS)
Turbocharger	TC	Turbo
Vehicle Speed Sensor	VSS	- Distance Sensor - Pulse Generator (PG)
Voltage Regulator	VR	voltage Regulator (VR)
Volume Air Flow	VAF	- Air Flow Control (AFC) - Air Flow Meter - Vane Air Flow
Volume Air Flow Sensor	VAF Sensor	- Air Flow Meter - Air Flow Sensor (AFS)
Warm Up Oxidation Catalytic Converter	WU-OC	Light Off Catalyst
Warm Up Three Way Catalytic Converter	WU-TWC	Light Off Catalyst
Wide Open Throttle	WOT	Full Throttle
Wide Open Throttle Switch	WOT Switch	Wide Open Throttle Switch (WOTS)

EDI Ford Industrial Engine Distributor List

AUSTRALIA

	All Marine Spares	10 Wilmette Place Mona Vale N.S.W. Australia 2103	61-2-99972788

EUROPE

FRANCE	Fornaut S.A.	45, Rue Charles Nodier, 93310 Le-Pre-St.-Gervais France	33-148-450-394 33 148-457-504
GERMANY	Sauer & Sohn Sauer Motive Systems	Gross Zimmerner Strasse 51 D-64807 Dieburg Germany	49-6071-206-330 49-6071-206-219
GREAT BRITAIN	Hendy Power	School Lane Chandlers Ford Industrial Estate, Eastleigh, Hampshire SO53 4DG England	44-2380-579-800 44-2380-271-471
	Power Torque Engineering	Herald Way, Binly, Conventry Warwichshire CV3 2RQ England	44-2476-635-757 44-2476-635-878
ITALY	Compagnia Technica Motori S.p.A.	Via Magellano 1, I-20090 Cesano Boscone, (Milano) Italy	39-02-450-581 39-02-450-582(60/62)
NETHERLANDS	My Power Products	Houtzaagmolen 41 MIJDRECHT Netherlands NL 364	03-129-758-1555

MEXICO

	Equipos y Motores Ind.	Ave. Cuitlahuac No. 700 Col. Popotla 11400 Mexico, D.F.	52-55-5341-9066

NORTH AMERICA - UNITED STATES

ALABAMA	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
ALASKA	Perkins Pacific	6100 S. 6th Way Ridgefield, WA 98642	877-877-3311
ARIZONA	Southwest Power Products	5143 W. Roosevelt Phoenix, AX 85043	602-269-3581
ARKANSAS	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
CALIFORNIA	Powertech Engines Inc (Main Office)	2933 E. Hamilton Ave. Fresno, CA 93721	1-559-264-1776 1-800-891-1776 1-559-264-2933
	Powertech Engines Inc.	1410 South Acacia Ave. Suite B Fullerton, CA 92831	1-714-635-1774 1-800-678-3673 1-714-635-1771
COLORADA	Anderson Industrial Engines Co.	5532 Center Street Ohmaha, NE 68106	402-558-8700
CONNECTICUT	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
DELAWARE	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
FLORIDA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
	Engine Distributors Inc.	2917 S. W. Second Ave. Fort Lauderdale, FL 33315	1-800-220-2700
GEORGIA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
HAWAII	Perkins Pacific	6100 S. 6th Way Ridgefield, WA 98642	877-877-3311
IDAHO	Perkins Pacific	6100 S. 6th Way Ridgefield, WA 98642	877-877-3311
ILLINOIS	Diesel Power Equipment	1211 Lyon Rd. Batavia, IL 60510	877-876-3732
INDIANA	McDonald Equip.	37200 Vine St. Willoughby, Ohio 44094	1-800-589-9025
IOWA	Anderson Industrial Engines Co.	5532 Center Street Ohmaha, NE 68106	402-558-8700
KENTUCKY	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
KANSAS	Anderson Industrial Engines Co.	5532 Center Street Ohmaha, NE 68106	402-558-8700

NORTH AMERICA - UNITED STATES

LOUISIANA	Engines , Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
MAINE	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
MARYLAND	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
MASSACHUSETTS	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2701
MICHIGAN	McDonald Equip.	1217 East Grand River Portland, MI 48875	1-800-445-5273
MINNESOTA	Diesel Power Equipment	13619 Industrial Rd. Omaha, NE 68137	800-999-5689
MISSISSIPPI	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
MISSOURI	Diesel Power Equipment	13619 Industrial Rd. Omaha, NE 68137	800-999-5689
MONTANA	Perkins Pacific	6100 S. 6th Way Ridgefield, WA 98642	877-877-3311
NEBRASKA	Anderson Industrial Engines Co.	5532 Center Street Ohmaha, NE 68106	402-558-8700
NEVADA	Southwest Power Products	5143 W. Roosevelt Phoenix, AX 85043	602-269-3581
NEW HAMPSHIRE	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
NEW JERSERY	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
NEW YORK	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
NEW MEXICO	Southwest Power Products	5143 W. Roosevelt Phoenix, AX 85043	602-269-3581
NORTH DAKOTA	Diesel Power Equipment	13619 Industrial Rd. Omaha, NE 68137	800-999-5689
NORTH CAROLINA	Engine Distributors Inc.	303 Interstate Dr. Archdale, NC 27263	1-800-220-2700
OHIO	McDonald Equip.	37200 Vine St. Willoughby, Ohio 44094	1-800-589-9025
OKLAHOMA	M.G. Bryan	1906 S. Great S.W. Parkway Grand Prairie, TX 75051	972-623-4300
OREGON	Perkins Pacific	6100 S. 6th Way Ridgefield, WA 98642	877-877-3311

NORTH AMERICA - UNITED STATES

EASTERN PENNSYLVANIA	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
WESTERN PENNSYLVANIA	McDonald Equip.	37200 Vine St. Willoughby, Ohio 44094	1-800-589-9025
RHODE ISLAND	Engine Distributors Inc.	41 Pope Road Holliston, MA 01746	1-800-220-2700
SOUTH CAROLINA	Engine Distributors Inc.	259 Ellis Rd. South Jacksonville, FL 32254	1-800-220-2700
SOUTH DAKOTA	Diesel Power Equipment	13619 Industrial Rd. Omaha, NE 68137	800-999-5689
TENNESSEE	Engines, Inc.	5400 C.W. Post Road Jonesboro, AR 72401	1-800-562-8049
TEXAS	M.G. Bryan	1906 S. Great S.W. Parkway Grand Prairie, TX 75051	972-623-4300
UTAH	Perkins Pacific	6100 S. 6th Way Ridgefield, WA 98642	877-877-3311
WASHINGTON	Perkins Pacific	6100 S. 6th Way Ridgefield, WA 98642	877-877-3311
WEST VIRGINIA	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
WISCONSIN	Diesel Power Equipment	13619 Industrial Rd. Omaha, NE 68137	800-999-5689
WYOMING	Perkins Pacific	6100 S. 6th Way Ridgefield, WA 98642	877-877-3311
VERMONT	Engine Distributors Inc.	400 University Court Blackwood, NJ 08012	1-800-220-2700
VIRGINIA	Engine Distributors Inc.	303 Interstate Dr. Archdale, NC 27263	1-800-220-2700

NORTH AMERICA - CANADA

ALBERTA, SASKATCHEWAN	Industrial Engines Ltd.	14355 120th Ave. Edmonton, Alberta Canada, T5L 2R8	780-484-6213
ALBERTA, SASKATCHEWAN	Simson Maxwell	8750-58th Avenue, Edmonton,AB Canada T6E 6G6	1-800-374-6766
ALBERTA, SASKATCHEWAN	Simson Maxwell	5711-80 Avenue SE,Calgary,AB Canada T2C 4S6	1-800-374-6766
BRITISH COLUMBIA	Simson Maxwell	1605 Kebet Way Port C, BC Canada V3C 5W9	1-800-374-6766
	Simson Maxwell	#12-4131 Mostar Road, Nanaimo BC, Canada V9T 5P8	1-800-374-6766
	Simson Maxwell	1846 Quinn Street, Prince George, BC Canada V2L 3H4	1-800-374-6766
MONTREAL	MARINDUSTRIAL	8550 Delmeade Montreal, QUEBEC Canada, H4T 1L7	514-342-2748
NEW BRUNSWICK, NOVA SCOTIA, NEWFOUNDLAND	DAC Industrial Engines, Inc.	10 Akerley Blvd., Unit 61 Dartmouth, NS, B3B 1J4	902-468-3765 877-468-3765
ONTARIO	MARINDUSTRIAL	2320 Bristol Circle, Unit 8 Oakville, ON L6H 5S3	1-800-866-3831

EDI Worldwide Service
Engine Distributors Inc.
400 University Court
Blackwood, NJ 08012
Service/Warranty
1-800-220-2700
1-856-228-7298
1-856-228-5657 (fax parts & service)
1-856-228-5531 (fax sales)